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August 1979

PROCEEDINGS
1978 Southern
Nursery Conferences

WESTERN SESSION-Hot Springs, Ark.
July 24-27, 1978

EASTERN SESSION-Colonial Williamsburg, Va.
August 7-10, 1978

Cosponsors: Arkansas Forestry Commission
Virginia Division of Forestry
USDA Forest Service–Southeastern Area
State and Private Forestry

ERRATA

Proceedings 1978 Southern Nursery Conferences:

Page 156 <u>should be</u> labelled 157.

Page 157 <u>should be</u> labelled 156.

The correct sequence should be:

B. Prevent weeds from going to seed.

C. Limit the spread of weeds which reproduce vegetatively.

II. <u>Mechanical Weed Control</u>

A. Cultivation

B. Separation of nutsedge tubers from the soil.

III. <u>Chemical Weed Control</u>

A. Pines

B. Hardwoods

C. Cover crops

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Combined proceedings of the western session (W) July 24-27 at Hot Springs, Arkansas, and the eastern session (E) August 7-10 at Colonial Williamsburg, Virginia.

"Compiler's Note"

Many individuals helped to make these conferences possible. My special thanks to Dennis Eagle and Jim Grant for their fine work in Hot Springs and to Bill King, Ron Wasser and all of the New Kent staff for an outstanding job in Williamsburg!

This proceedings is dedicated to two of our nurserymen who were not able to join us at Hot Springs and Williamsburg. Gerald Black (Weyerhaeuser - North Carolina) died on May 13, 1978 in his 8th year as Nursery Superintendent. Gerald Williams (Pinson - Tennessee) died on October 29, 1977 after 29 years as a state nurseryman. We miss them both.

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GERALD W. BLACK
(6/10-38-5/13/78)

Gerald Black was born in Washington, N. C. and attended school at Bath, N. C. He graduated from East Carolina University.

He spent two years in the US Army and 12 years with Hackney and Sons, Washington, N. C. as Equipment Development Supervisor. From 1970 to 1978, he was Nursery Superintendent at the George Hunt Walker Weyerhaeuser Nursery, Washington, N. C.

Gerald made many significant contributions to the establishment and maintenance of the nursery. He also provided a great deal of technical assistance, advice and suggestions to other southern nurserymen through both conferences and individual contacts.

He initiated research studies on hardwood growth, herbicides, progeny test seedlings and seedling volume growth.

He had a great deal of mechanical ability which led to the design and construction of packing room equipment, a field packing trailer, a fertilizer spreader, bed shaper, wrencher-undercutter, lateral pruner, subsoiler, inventory cart, irrigation pipe trailer and self-propelled weeding machine.

His dynamic approach to nursery management and his many accomplishments will be remembered for a long time.

GERALD T. WILLIAMS
(4/10/22-10/29/77)

Gerald Williams served six years in the U. S. Navy and was assigned to the battleship Maryland at Pearl Harbor (December 7, 1941).

He started work with the Tennessee State Nursery at Pinson in January of 1948. He had served the nursery well for over 29 years at the time of his death.

Gerald will be remembered for his dedication, hard work and his many accomplishments at the Pinson Nursery. He always did much more than was expected of him.

A special quality was his delightful sense of humor and ready wit. He will be sorely missed by all those who were privileged to know and work with him.

Nursery Retirement

Resume

Name: IDA MAE (MACY) MOSELEY

Birthplace: Greensboro, N. C.

Education: Macon, Georgia Public Schools

Employment: November 1955 - Region 8 Seed Testing Lab (later became the Eastern Tree Seed Lab). Retired in 1977 after 22 years as Lab Assistant, Seed Technician, and Germination Analyst.

Special Accomplishments: Worked for Tom Swofford, LeRoy Jones, Darrell Benson, Tom Waldrip, Jim McConnell and Earl Belcher.

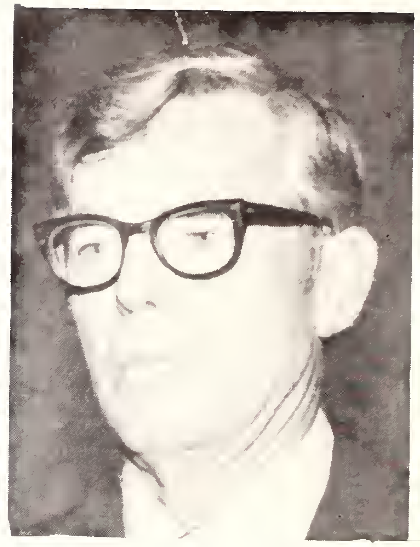
Outstanding Service Award - 1972

The first Germination Analyst in the State of Georgia

Established a solid reputation as a loyal, dedicated, efficient seed technician and germination analyst. She will long be remembered for her cheerful, helpful attitude toward her work and all those whom she contacted.

Nursery Retirement

Resume



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Birthplace: Portal, Georgia

Education: High School Graduate
Short Course Training in Genetics & Nursery Management

Employment:	USDA - 1940-1944 - Crop Reporter	
	Georgia Forestry Commission	1944-1946 - Marketing Aide
	" " "	1946-1956 - County Ranger
	Continental Group, Inc.	1956-Present - Nursery Supervisor

Special Accomplishments:
Recognized by his superiors as being responsible for the management of an outstanding nursery.

Retirement Plans;
Travel and visits with grandchildren

GROUP PHOTO - HOT SPRINGS

GROUP PHOTO - WILLIAMSBURG

GROUP PHOTO - WILLIAMSBURG

GROUP PHOTO - WILLIAMSBURG

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THE INFLUENCE OF FORESTRY TRENDS ON NURSERY OPERATIONS

BRUCE ZOBEL 1/

INTRODUCTION

No matter how good the seed, or how good its genetic potential, the success of a planting program is always greatly dependent on the quality of the trees produced in the nursery. Physiological conditioning of nursery stock has both short-range and long-range effects. For example, a heavy fertilization late in the season can produce "saleable" seedlings that may later be easily killed by drought or freezing weather after outplanting. The effects of nursery conditioning (physiological condition of the seedlings) was continually emphasized by specialists such as Phil Wakeley who also showed the effects can last for many years after planting. Similar results have been observed in our extensive field tests; for example, we have an absolute rule to never establish a test with seedlings produced in different nurseries.

This paper will briefly cover the effects of new forestry trends on nursery operations. The message of importance is that nursery practices play a critical role in successful plantation establishment and growth no matter what the trends in forest management. Additionally, new forestry methods will result in some changes in nursery operations.

1/ Professor, Forest Genetics, School of Forest Resources, North Carolina State University, Raleigh, North Carolina.

WHAT'S NEW!

In Tropical Areas

The relationship of field operations and nursery procedures is key in tropical and sub-tropical areas where changes take place rapidly. Sometimes changes in forest management strategy are massive and rapid.

1. In order to mechanize and to speed up operations and save cost, there is a strong move in the tropical areas to change as rapidly as possible from the conventional containerized seedlings now widely used to bare-root or semi-bare root stock. Semi-bare root refers to dipping roots in a mud slurry, a method that has proven to be very successful and is in widespread use. Some species, like *P. caribaea* and *P. radiata*, appear to respond well to bare-root planting, while others such as *P. oocarpa*, *Cupressus lusitanica* and most of the Eucalyptus are not so well suited to its use. Bare-root planting in the tropics is difficult for several reasons:
   a. Trees in nurseries in the topics often grow very rapidly in height resulting in a poor top-to-root ratio.
   b. The planting season is often during or near the dry season, with only seedlings in the best physiological condition able to survive and grow. Drought can be very severe and of long duration; this is especially serious in the deep sands and the very heavy clays which often shrink (and crack) to a frightening degree.
   c. Day temperatures usually are very warm, often with low relative humidity and strong drying winds. Some organizations have partially overcome these conditions by doing bare-root planting at night.

d. Growing conditions in the nursery are often so ideal that it is difficult to suitably harden-off seedlings prior to planting. The nurseryman's efforts to produce well balanced and physiologically suitable stock are often thwarted by nature. If there were ever a challenge to the nurseryman's skill, it is the developing of suitably hardened plants under these conditions.

2. Planting programs in the tropical areas have in many instances become very large and the old "backyard" concept of a small nursery for every planting location is rapidly changing. With the need for large numbers of seedlings has come the necessity for mechanization and specialization in nursery operations, currently nearly totally lacking in many operations.

3. The planting season may be year-round in some areas making the concept of a "one crop a year nursery" obsolete. An extreme example is in Esperito Santo, Brazil, where one company I work with plants containerized eucalypts all 12 months of the year. The need for removal of seedlings from the nursery is continuous and a new crop is sown approximately every two weeks.

4. Mycorrhizae are often lacking or are found in limited numbers. Some nurseries have special "mycorrhizae beds" (pine plantings) from which duff or soil is put on the trees in the nursery beds or on/and in the containers. Pure cultures of mycorrhizal fungi such as *Pisolithus tinctorius* are occasionally being used. Lack of mycorrhizae is a major problem in tropical plantations, and must be of major concern of the nurseryman. Too few nurseryman have a viable working concept of mycorrhizae and their management in the nursery.

In Northern Areas

Similar to the tropics, much of the stock recently produced in the northern regions has been containerized. It has taken so much time to grow bare-root stock such as spruce or fir (2-3 or 2-2 stock is not unusual) using the old methods that an inordinate amount of time, and thus nursery space and cost, was involved. The long period between sowing in the nursery and outplanting in the field is critical, making planning of regeneration programs difficult. Containerization, plus the use of plastic houses, have resulted in the production of good seedlings in a shorter time period. As planting programs continue to rapidly increase in size, (such as in New Brunswick, Canada), the logistics of producing sufficient containerized trees becomes very difficult. The current trend towards better site preparation, more planting mechanization and an increasing use of jack pine, larch and black spruce (as opposed to red and white spruce) has resulted in a greater emphasis on the production of bare-root seedlings in a reduced time period. Great success has been achieved; for example, fine 2-0 pine are now produced in Saskatchewan. The challenge to the nurseryman is to get physiologically suitable seedlings to a satisfactory size in the shortest possible time to enable the mass planting programs to function efficiently.

The better knowledge and techniques of nursery practices, and increasingly large regeneration programs, will dictate more emphasis on bare-root planting in the colder latitudes. This will not only require more skills by the nurseryman, but better choice of nursery sites combined with the use of better genetic stock and better seed. Mycorrhizal management, as well as fertilization, will be essential to produce seedlings with the survival and early growth so essential in the severe environments in the north. The kind of management methods now being increasingly employed, with their attendant high costs,

cannot tolerate poor or spotty stocking in plantationsestablished on the best lands.

In the Southeastern U. S.

I see little radically new in our area, but certainly some major refinements of current techniques will be essential. The current methods must be modified as follows:

1. To obtain the highest plant to seed ratio possible. With the almost universal use of genetically improved seed, loss of large numbers of seedsin nursery operations can no longer be tolerated. Nursery bed densities will need to be reduced with great care being taken to enable seedlings to become plantable. Even though it may sound "far out" to some of you, sowing seed in the nursery bed by clone or family will probably become more general because it enables a much more efficient biological handling of the nursery operation. Seeds of the same size, germinate at the same rate and respond to stratification in the same way. We find, for example, that seed of some loblolly pine mother trees react adversely to stratification. Only by handling as discrete seed lots can this information be used. Such special planting is now being done by one large organization in the South and appears to be very successful.
2. To ensure optimal survival when field planted. Although this meeting is not the proper place to discuss desired plantation spacings, all spacings used in an extensive plantation program require complete stocking; this requires the seedlings to be physiologically and genetically the very best for the planting chance. The role of the nurseryman is key here--no matter how good is the seed potential, sloppy nursery practices

resulting in a seedling in poor physiological condition can result in poor survival and poor initial growth. I recently visited several nurseries in which the seedlings had not developed well, so the nurseryman gave them "a shot of nitrogen late in the season" to make them plantable. Such practices result in succulent seedlings that usually have a poor field performance and are inexcusable for a good nurseryman. Additionally, survival and early growth on many sites relates to the condition of the mycorrhizae of the seedlings roots.

3. <u>More care must be taken than in the past to prevent lifting the seedlings when they are in a physiologically unsuitable condition.</u> As planting programs become increasingly large, strong pressures are present to expand the planting season, both earlier and later than normal. This has resulted in some rather horrifying fiascos, such as lifting before the seedlings are physiologically ready or after the plants have started active growth in the spring. I submit that these can be lessened when the nurseryman learns that the whole nursery need not be planted at one time as a single unit. One of the greatest challenges to the nurseryman today is to learn to seed in the nursery at differing times and to manage the seedlings in different ways so they will become suitable for outplanting at different times enabling more efficient forest management. Even the suggestion to use differential planting times and to adjust nursery management techniques to harvest crops at different times causes consternation with many nurserymen, but I know of no one challenge (opportunity) greater than to <u>really</u> manage the nursery so seedling production is fully compatible with field planting needs. Today, the general pattern is to produce seedlings at the convenience of the

nurseryman who then tells the forest manager "here they are--do what you can with them". The expanded regeneration programs will make this narrow approach by the nurseryman no longer tolerable. Developing suitable plants when needed will take real skill and trial and error testing, but it appears to me to be one of the greatest current needs of nursery activities caused by increasingly large regeneration programs. Production of physiologically suitable seedlings several times a year from a given nursery is a major challenge to southern nurserymen and one they have generally ignored or said couldn't be done. If the trends toward expanded forest management and increased planting programs are to be successful, this must be done, through timing in nursery activities and changes in management methods.

4. I do not foresee containerized seedlings playing a major role in southern pine or hardwood forest nursery operations. They will be used for special conditions, but always on a limited scale. A seedling in good physiological condition, handled correctly with the roots protected by methods such as clay slurries, has most of the supposed advantages of a containerized seedling plus being easier and cheaper to produce. I do see an expansion of containerization for very slow starting species such as Fraser fir and possibly white pine for which vigorous, well developed seedlings can be produced in a much shorter time with containers compared to using current standard nursery methods. I would not be surprised to see the use of numerous, small and inexpensive plastic houses (as used in Finland) near the planting site when containerization is more suitable rather than the larger more expensive greenhouses now often in use.

SUMMARY: THE FUTURE! THE PREDICTIONS! THE OPPORTUNITIES!

If one wants to live dangerously, he will predict what will happen in the future in forestry--or in nursery methods. However, a non-specialist in nurseries such as myself has the advantage of not knowing what the traditional nurseryman says can or cannot be done--therefore, I don't even blush to walk where "fools fear to tread" and make predictions about the future. For your consideration, therefore, some ideas from a non-nurseryman of what can or should happen to nursery operations resulting from changing and predicted forestry trends are presented:

1. In the tropical and sub-tropical areas, pines such as *P. caribaea* and *P. radiata* will be planted largely bare-root to enhance mechanization and reduce costs; other species will be handled using a modified bare-root system. In addition:
   a. Nurseries will become larger, more centralized, more mechanized and more efficient. In many instances, single crops of seedlings will not be grown, but several will be produced during the year to coincide with planting opportunities. In some special situations nursery sowing may be as frequent as every two weeks.
   b. A great deal more and better mycorrhizal management will be done to enhance better nursery growth and field survival.
2. In the northern latitudes (Canada, Northern U. S.), there will be a trend towards planting black spruce, pines and larch, and a trend away from the white and red spruces. This makes feasible the production of more bare-root seedlings and less containerized seedlings. Better care in nursery location and management operations and timing will result in production of bare-root seedlings as 2-0, 1-1, or even 1-0 stock, currently not considered to be possible.

3. In the South, there will not be a movement towards large scale containerization in either pines or hardwoods; containerization will probably become more widespread for special problem sites or for initially slow growing species such as Fraser fir.

   a. A major effort will be made to improve the plant to seed ratio. This will require nursery beds with lower densities or radical changes such as nursery sowing by clone (or family) for better plant to seed ratios and more uniform nursery seedlings.

   b. Better handling and better seed will be necessary to ensure optimum survival and good initial growth, an absolute necessity with intensive forest management.

   c. Methods will be developed to extend the planting season by producing physiologically suitable seedlings plantable as needed rather than produce a single crop all of which is available at one time.

4. In the future, forest management intensification and specialization will continue requiring regeneration in times and places not now considered feasible. Nurserymen must rise to the challenge so physiologically suitable seedlings will be available when needed at a reasonable cost.

FOREST MANAGEMENT IN VIRGINIA

Caleb M. Pennock, Jr.[1/]

Abstract.--Virginia's Forest Management Program places emphasis on increasing sound timberland management on the small private ownerships and the regeneration of poorly stocked and cutover stands. This is done by providing technical services, financial assistance, vendors and specialized forestry equipment. The future will demand bold innovations and new technology in forest management techniques. Forestry programs must meet this challenge to insure an adequate forest resource for future generations.

Reforestation or forest tree planting has been on the increase since 1956 in Virginia and has leveled off to approximately 85,000 acres annually. In 1972, a mile stone was reached when the small private, non-industrial forest landowners planted more acreage than the forest industry. This was an important accomplishment for Virginia since the small private landowners own about 77% of our total commercial forestland.

Our 1966 Forest Survey indicated that the pine resource was in danger due to overcutting. Statewide, the pine was being cut about 15% faster than growth. In the Coastal Plain and Southern Piedmont Regions, where the majority of the pine is located, the situation was bad. The drain exceeded growth by 33% in the Coastal Plain and 25% in the Southern Piedmont. As a result, Virginia enacted the first state incentive program for reforestation work in the Nation. Our 1977 Forest Survey shows very encouraging results. The pine drain has been reduced from 33% to 7.8% in the Coastal Plain. In the Southern Piedmont, the pine growth now exceeds the drain by 22%.

The small private non-industrial forest landowners own about twelve and one-half million acres of the total commercial forestland in Virginia. They are the "key" to our future forest resource supply. Also, about 185,000 acres must be regenerated annually just to replace harvested stands. Thus, priority must be given to the regeneration of each acre harvested and retained in commercial forest. Therefore, the forestry programs in Virginia are directed towards increasing sound timberland management on small ownerships and the regeneration of poorly stocked and recently cutover stands.

There are 75 County Foresters in Virginia. Also, each county has a Chief Forest Warden, who is a non-professional, on a full time basis. The County Forester concentrates on the Forest Management Program to assist non-industrial landowners even though he is responsible for all Division activities within his area. The Chief Forest Wardens' main responsibility is Fire Control. However, both individuals become involved in all Division activities and, as a result, they form a strong team on the local level.

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Our County Foresters will follow their recommendations to the landowner through to completion. He will assist the landowner in any way possible within the framework of policy that is necessary to get the job done. If he recommended drum chopping, prescribed burning and planting, the forester will make all the necessary arrangements to have the private vendors, equipment and manpower available to do the forestry work. To insure good quality seedlings for planting projects, the County Forester or the Chief Forest Warden will deliver the seedlings at regular intervals, depending upon weather, to the planting crews. This has been made possible due to our cold storage units located throughout the state. Planting bags are also provided to the planting crews to encourage proper handling of the seedlings during planting. In addition, they will inspect the job during and after completion to insure quality work.

Our foresters are also required to make reinspections of two and three year old projects to see the results of their advice. This gives the forester the opportunity to assess the results and make further recommendations to the landowner, if needed. As a result, from these reinspections, this year we chemically released, by air, 9,000 acres of pine from competing poor quality hardwoods. This strong follow-up program has increased our forestry accomplishments with the private non-industrial landowner in Virginia.

Forestry incentive programs have been very successful in Virginia. In fact, they have proven to be the catalyst needed to interest the private, non-industrial landowner to do intensive forest management. There are three separate incentive programs in Virginia. They are the State program, known as the Reforestation of Timberlands or RT, and the two Federal Programs (FIP and ACP). Together, these three incentive programs are responsible for 50,000 acres being planted or improved for timber production annually for the past four years. This year, approximately 1.5 million dollars of incentive funds will be spent for this purpose. If we take the landowner's cost into account, about 2.2 million dollars will be spent on forest management by the private, non-industrial landowners in Virginia in 1978. Virginia has a ten year goal to plant 800,000 acres of pine by 1980 in order to bring the growth of pine into balance with drain. At the present time, the past seven year average for planting is 82,000 acres which is a very encouraging figure. If we maintain this average, we should top our pine planting goal in 1980. It is estimated that 90% of the reforestation accomplishments on small private ownerships in Virginia has been the direct result of the State and Federal incentive programs. We feel that the loss of any segment of this effort would hamper the end results and endanger the future of our forest resource.

There must be someone available to do the work on the tract in order to get the forestry work completed. To meet this end, our organization had to interest and train private vendors to do all types of forestry work. This requires a lot of time, patience and constant insisting on quality work by our foresters. As a result, we now have available over 350 to 400 private vendors that will do various kinds of forestry work. In this way, we can be assured that when a forester recommends a forestry practice, there will be a contractor available to do the work. It has been our policy to develop private enterprise to provide the needed forestry services on a business basis.

In addition, the forest industry in Virginia has been very cooperative in assisting the landowner in doing forestry work. They have used their own personnel and equipment for either the site preparation work or doing the total reforestation job. Together, the private vendors and the forest industry have made it possible for the private, non-industrial landowner to do the forestry work as recommended by the forester.

Forestry work requires specialized equipment such as drum choppers, heavy disks and open field and wildland tree planters. Due to their limited use and costs, most private vendors and landowners cannot afford to purchase this type of equipment. Therefore, our organization purchased specialized forestry equipment to be rented to landowners and vendors to assist them in doing forestry work. At the present time, we have:

(a) 27 drum choppers ranging in length from 7 to 10 feet; the majority being 8 feet. In 1977, 11,500 acres were chopped on private, non-industrial land. (Rental fee $2.50 per acre.)

(b) 9 two ton bush and bog disks ($2.00 per acre).

(c) 2 five ton bush and bog disks ($5.00 per acre).

(d) 51 open field planters ($1.25 per acre).

(e) 15 wildland tree planters ($2.50 per acre).

(f) 11 back pack mist blowers ($1.00 per acre).

(g) 1,800 planting bars free on request.

(h) 1,500 planting bags for planting crews.

The County Foresters keep close contact with the vendors who are willing to use this equipment on private land and he coordinates its use within his area of responsibility. If necessary, the County Forester will take the time to train vendors in the use of this equipment. According to our policy, here we are trying to develop private enterprise to do the needed forestry work in Virginia. This policy has had a significant impact on the local economy by providng employment for additional persons.

Virginia has a Seed Tree Law that requires landowners or timber operators to leave eight pine or two yellow poplar seed trees per acre when timber is harvested. However, in lieu of leaving seed trees, a landowner or timber operator may apply to the State Forester for an Alternate Management Plan which requires the establishment of pine by planting or direct seeding within a specified period of time. The applicant must do all the necessary site preparation such as drum chopping, prescribed burning, disking or bulldozing in preparation for planting. He is also required to have a minimum of 400 surviving seedlings per acre at the end of the first growing season. At the present time, there are 900 Alternate Management Plans to be completed amounting to 48,000 acres. Approximately 300 Alternate Management Plans are processed or completed annually totalling about 16,000 acres.

We have been pleased with our accomplishments in our forest management program for the small private, non-industrial landowner. We have found that to reach the small landowner, we must provide the technical assistance, financial incentives, the necessary equipment and vendors to do the work. Also, forestry programs must take the needs and objectives of the landowner into account. In most instances, landowners are ready and willing if they can be shown how it can be done.

It was not my intent or purpose to tell you that Virginia has solved the problem with the small forest landowner. We have not. There are many challenges that we must solve to meet the forest resource needs of the future. These challenges are:

1. Utilization: The increasing demand for forest products, environmental concerns and pollution control are all making us more aware of the need to minimize waste and to maximize yield in the field and at the sawmill.

2. Tree Improvement: Today, greater attention is being given to reforestation practices. The South, in particular, has undertaken an ambitious tree breeding program designed to increase the yield of the next pine forest. Trees with superior traits have already been selected and orchards have been established for seed production.

3. Quality Seedlings: We need quality seedlings to meet the demands for reforestation. Nurseries must be in a position to produce quality seedlings. This will require careful attention to irrigation, fertility, weed control, root pruning and other cultural treatments.

4. Site Preparation: Adequate site preparation is now recognized as a vital component in reforestation. Additional research efforts should concentrate on more cost effective methods of site preparation.

5. Regeneration Techniques: Improvements in planting and seeding technology must complement tree improvement, nursery and site preparation programs. Due to rising labor cost, there are opportunities for mechanization and low cost operations.

6. Environmental: Attention is now being focused on the environmental impact of all forestry activities. As a result, we may be required to develop new technology in forest management techniques.

7. Urbanization: Public recognition of the numerous benefits derived from the forest resource, other than pulpwood and lumber, is one of the outstanding developments of recent years. Forests are valuable for aesthetic, recreation, open space, noise abatement, greenbelts, wildlife and watershed purposes. We must develop our programs to meet these needs.

8. Private Ownerships: Finally, sound forest management must be extended to the idle forestland owned by small private ownerships. In the South alone, 70% of the commercial forests are in this ownership class, so this is a critical area and the key to our future forest resource.

In summary, there is quite a challenge facing forestry today. It will demand bold innovations as well as changing or modifying existing methods and techniques. The success of the future in forestry will be highly dependent on all of us.

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TREE IMPROVEMENT RESEARCH

Ronald G. Wasser 1/

Abstract.---Open pollinated seed from five clones was sown in both "pure" plots (clones kept separate) or "random" plots (a random sowing of all five clones together). Average root collar diameter of 1-0 seedlings varied by clone and sowing method. For clones with seed that germinated rapidly, random sowing produced larger seedlings than pure sowing. But for clones with seed that germinated slowly, pure sowing produced larger seedlings than random sowing.

General collections on all tested clones can begin at least three weeks earlier than normal for loblolly pine with no significant decrease in seed yield or quality.

Slash pine cones stored in one bushel sacks had 30 percent greater seed yield and the required opening time was reduced by 40 percent compared to cones stored in 20 bushel boxes.

Key Words.---Progeny testing, germination, cone collection, seed yields, cone storage.

PURE VS. RANDOM SOWING STUDY

Introduction

Seed for progeny tests is sown in small plots by family, but for operational sowing, in most cases, a random mixture of the seed from all clones in a seed orchard will be sown in the nursery. The objective of this study was to observe any differences in seedling size and field performance that might occur as a result of sowing clonal seed lots either separately or in random mixture. If orchard seed harvesting becomes mechanized using either vacuum harvesters or seed net, separate sowing of clonal seed lots will be impossible.

Methods

Five of our Piedmont loblolly pine (*Pinus taeda*) clones were selected to give a range in speed of germination and size of seedlings produced in the seedbed. Of the five clones, three (506, 508, 512) were Virginia Division of Forestry trees, one (14-15) was a Continental Forest Industries tree, and one (6-10) was a Hoerner Waldorf (now Champion International) tree. The seed used was

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open pollinated seed from the 1972 harvest. The seed from these five clones was sown both in "pure" plots (clonal seed lots separate) and in "random" plots (a random sowing of all five clones together). Each clone was color coded in the nursery bed using colored toothpicks, and all were hand sown in rows six inches apart with two seeds placed every 2/3-inch within rows. The desired density was 36 seedlings per square foot. Where both seeds germinated in a spot one of the seedlings was removed. Sowing treatments were replicated four times. Final density was 29.8 per square foot in the pure plots and 28.4 in the random plots.

Seedbed Results

As expected, the five clones varied considerably in speed of germination (Figure 1). Clone 508 was the most rapid, followed closely by 512. Considerably slower was clone 14-15, then 506, with 6-10 by far the slowest.

In the pure sown plots there was little difference in average root collar diameter when the 1-0 seedlings were lifted in February (Figure 2). The slightly larger diameter of clone 6-10 seedlings was probably due to lower density in the pure plots of this clone (20 seedlings per square foot vs. a range of 28 to 30 for the other four clones). Clone 6-10 was a very slow germinator with the final or total germination of less than 40 percent (Figure 1).

In the random sown plots, on the other hand, there were considerable differences in average root collar diameter when the seedlings were lifted. (Figure 2) These differences seem to be related to speed of germination, with clones 508 and 512 being the fastest germinators and being the largest. Apparently they were able to get a head start on their slower germinating neighbors and gain a dominant position in the seedbed. This is reflected in the differences in percent of undersized (cull) seedlings produced (Table 1). In the pure sown plots the percent of undersized cull seedlings ranged from a low of 11 percent for clones 508 and 14-15 to a high of 19 percent for 512.

Field Planting

After lifting and measuring, the seedlings were planted in the field. The seedlings from the randomly sown plots were placed in racks so that in the field each seedling had the same neighbors it had in the nursery bed. Where missing spots occurred in the seedbed plots, commercial check seedlings were planted in the field. Seedling heights have been measured annually.

Height growth differences in the field reflect seedbed differences, and have gradually increased over the five years since the study was outplanted. After five years in the field, for clones 508 and 512, the two fastest germinators, seedlings from random sown plots are .5 foot taller than seedlings from pure sown plots. Apparently the competitive advantage they had in the random seedbed has carried over to the field. For clone 6-10, the slowest germinator, seedlings from random sown plots are .8 feet shorter than seedlings from pure sown plots. Here the competitive disadvantage in the random seedbed has apparently carried over to the field.

FIGURE 1

1973 LOBLOLLY RANDOM SEED SOWING STUDY GERMINATION DATA FROM PURE SOWN PLOTS

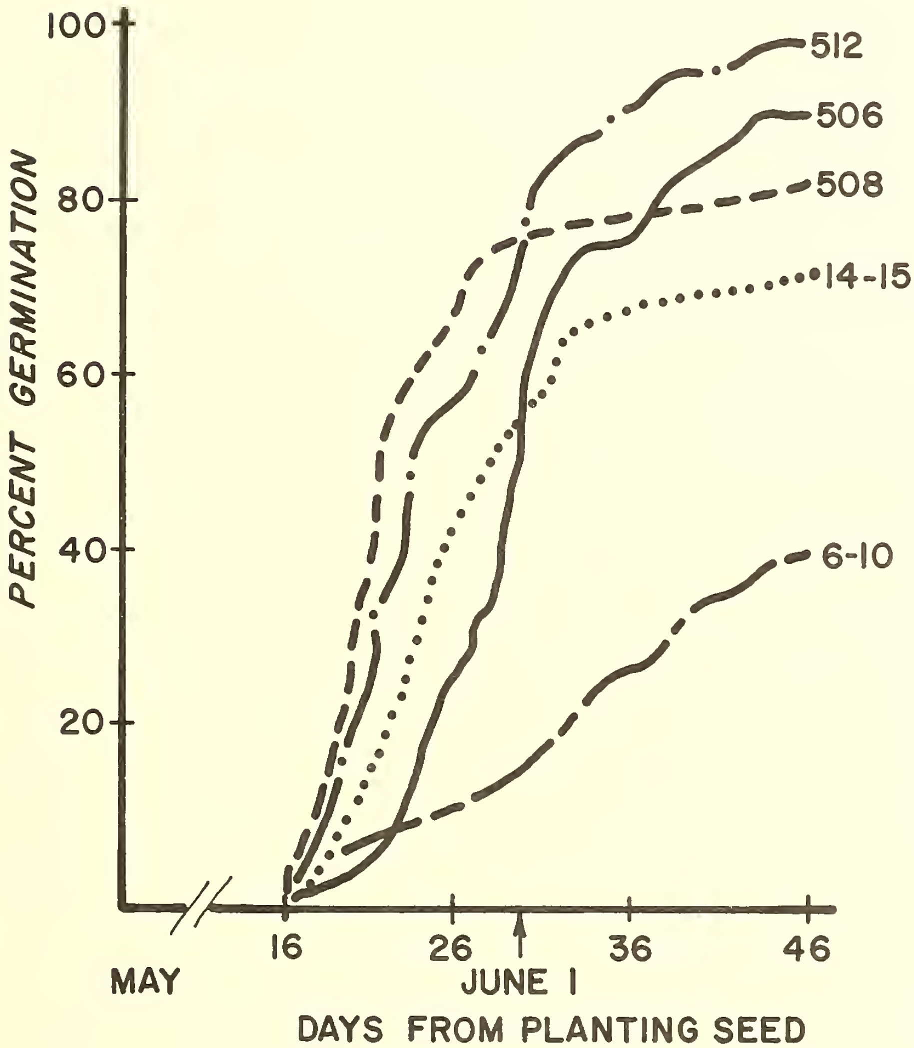
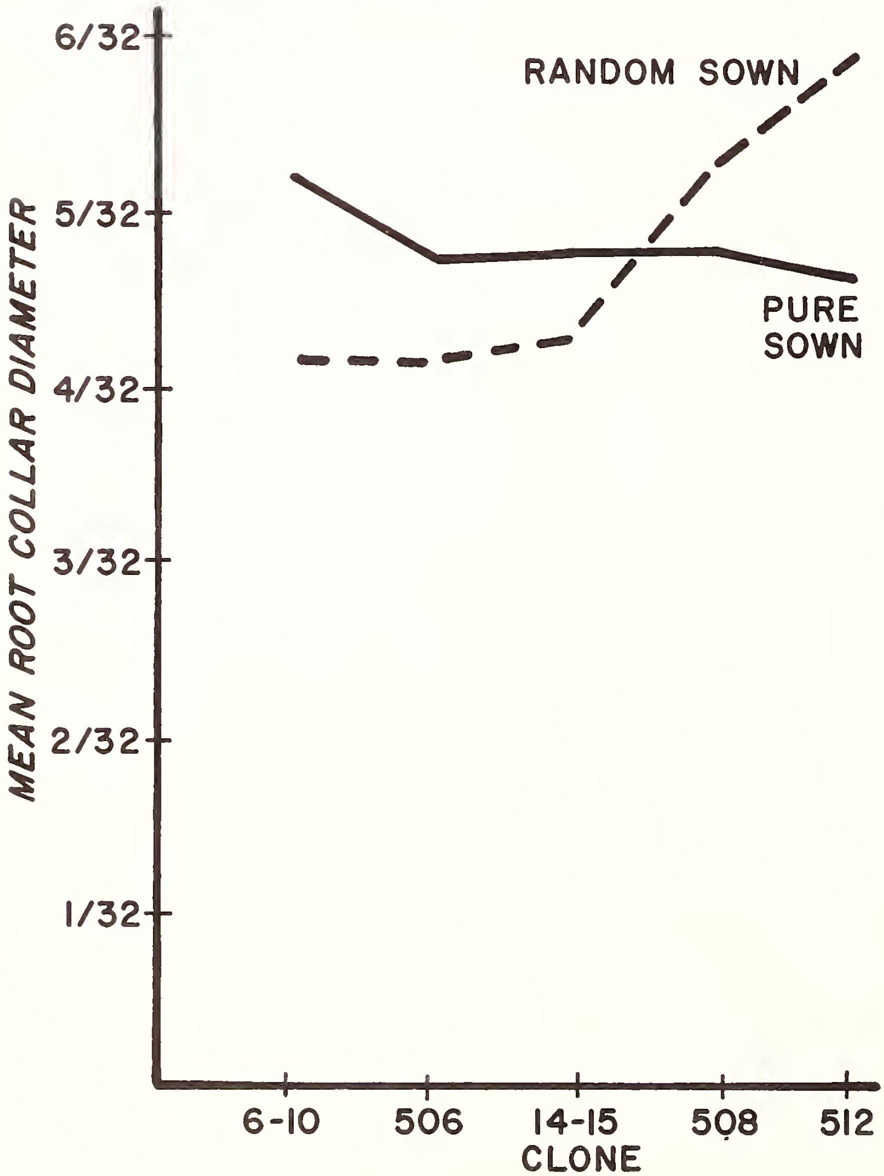


FIGURE 2

1973 LOBLOLLY RANDOM SEED SOWING STUDY
CLONAL MEAN ROOT COLLAR DIAMETERS



1973 LOBLOLLY RANDOM SEED SOWING STUDY - ROOT COLLAR DIAMETERS (1/32")

OF 1-0 RANDOMLY SOWN SEEDLINGS WHEN LIFTED

FAMILY	MEAN DIAMETER	% OF 2 & 3/32"
512	5.88	7
508	5.37	4
14-15	4.26	19
506	4.17	22
6-10	4.14	37

Table 1

LOBLOLLY EARLY CONE COLLECTION STUDY

Introduction

The objective of this study was to determine which of the seed orchard clones, if any, could be harvested early in the season with both acceptable seed yields and germination. With the normal collection season usually beginning about October 1, the identification of early ripening clones (even though the cones may not float in SAE 20 motor oil) could possibly extend our hand collection period by 20 percent or more.

1975 Test

The study was initiated in September 1975 when five loblolly clones (two Piedmont and three Coastal Plain) were selected. These clones were some of the heaviest cone producing clones at the time. Three typical ramets per clone were selected in the oldest orchards (approximately 14 years of age). With the normal collection period based on past experience beginning during early October, we decided to collect six healthy cones per ramet weekly beginning during early September and continuing through early October, for a total collection period of six weeks.

Procedure

Immediately after each collection, the six cones per ramet were bagged in small burlap sacks, labeled by ramet and date of collection, and placed in a lath shade house covered with 50 percent shade cloth. All sacks were wet down daily and turned weekly in an effort to artificially mature the collected cones and seed.

After the last collection date (normal collection time of early October), the frequency of watering decreased to about once a week in an effort to dry the cones slowly at ambient temperatures. During late October, the cone sacks were placed in the nursery cone drying wagons and dried for 48 hours. Each lot was then hand extracted, collecting those seeds which were easily "bumped" from the cones. The cones were then bagged again, soaked down, redried, and a second extraction (difficult) was made in an effort to determine if the second seed yields were really worth the effort. Finally each cone was manually dissected and a count made of the number of seed remaining in the cones. Seed yields, seed size, and total seed germination percentages were calculated and reported by the Virginia Seed Test Laboratory.

Results of 1975 Test (Table 2)

1. Mold problems occurred on some of the earliest collections and contributes to the reduced germination.

1975 EARLY CONE COLLECTION STUDY - LOBLOLLY

FIRST AND SECOND SEED EXTRACTION

Hill/Clone	Seed Extract	Test	Cone Collection Dates 9/4	9/11	9/18	9/25	10/2	10/9
G 506	1st	# Seed	1126	1537	1188	1305	685	812
	"	Germ %	7	31	100+	89	90	99
	"	Seed/lb	17,503	17,945	16,602	15,666	15,542	16,368
	2nd	# Seed	359	134	305	330	555	523
	"	Germ %	1.25	21.76	46.33	70.25	100+	100+
	"	Seed/lb	19,034	18,313	17,326	16,122	15,664	17,646
R 523	1st	# Seed	939	1255	1110	1210	1433	1251
	"	Germ %	94	87	80	91	100+	100+
	"	Seed/lb	20,345	18,224	17,766	18,211	16,631	17,000
	2nd	# Seed	421	330	219	182	112	66
	"	Germ %	45.50	63.33	55.50	59.00	78.00	60.60
	"	Seed/lb	21,662	19,997	19,067	19,295	16,757	19,069
J 2-8	1st	# Seed	1292	973	1074	965	900	1093
	"	Germ %	46	82	95	98	100+	95
	"	Seed/lb	20,571	19,126	19,428	18,403	17,652	18,068
	2nd	# Seed	161	262	427	405	594	241
	"	Germ %	43.50	74.67	75.25	82.50	100+	79.50
	"	Seed/lb	19,854	19,126	19,089	18,694	17,878	19,649
R 525	1st	# Seed	846	789	689	524	822	700
	"	Germ %	98	91	100+	100+	100	99
	"	Seed/lb	17,371	16,162	15,451	16,851	15,996	16,010
	2nd	# Seed	41	87	108	153	118	37
	"	Germ %	63.41	59.77	79.00	80.50	66.00	64.86
	"	Seed/lb	17,545	18,161	16,074	17,641	16,254	16,987
S 529	1st	# Seed	856	870	841	877	671	1230
	"	Germ %	75	91	89	91.72	99	100
	"	Seed/lb	16,441	15,544	14,619	15,190	13,683	14,144
	2nd	# Seed	453	425	477	273	642	281
	"	Germ %	58.52	75.25	96.13	76.00	100+	82.66
	"	Seed/lb	16,303	16,808	15,069	15,292	13,781	14,498

Table 2

2. All collections on tested clones could begin at least 3-4 weeks earlier than normal.

3. It appears that clones 523 and 525 could safely be collected as much as five weeks earlier than normal.

4. The smaller, more difficult seed to extract germinated quite well and would probably justify extraction costs. The average percent recovery for the first extraction for all five clones combined was 81.8 percent. An additional 17.9 percent was recovered in the second extraction.

1976 Test

A similar study was repeated in the fall of 1976 to include seven new clones. Clone 506 was included as a check against the previous years study. All procedures were identical to 1975.

Results of 1976 Test (Table 3)

1. Scattered mold problems again occurred primarily on the August 31 and September 7 collections.

2. All collections on tested clones could begin at least three weeks earlier than normal with some new clones 4-6 weeks earlier than normal.

3. Clone 506 performed as in the 1975 test. That is, in both years tests showed this clone could only be picked 2-3 weeks earlier than normal.

4. The smaller seed again appeared to be good enough to justify second extraction costs.

Overall Results of Both Tests

1. Twelve of the heaviest producing loblolly clones have been screened for early collections. Of these, four clones canbe collected as early as September 1, or five weeks earlier than normal.

2. General collections on all tested clones can begin at least three weeks earlier than normal.

3. Our general collection period has been increased from five weeks to eight weeks for the majority of the clones, with no significant decrease in seed quality.

1976 EARLY CONE COLLECTION STUDY - LOBLOLLY

FIRST AND SECOND SEED EXTRACTION

Hill/Clone	Seed Extract	Test	Cone Collection Dates 8/31	9/7	9/14	9/21	9/28	10/5
B 6-13	1st	# Seed	2110	1908	2000	1973	2377	2296
	"	Germ %	45.4	66.8	83.0	87.6	86.3	95.8
	2nd	# Seed	441	363	354	486	369	362
	"	Germ %	40.30	46.13	76.69	90.0	70.88	79.40
D 4-18	1st	# Seed	1823	1934	1812	2044	1955	1922
	"	Germ %	39.2	57.5	70.3	77.9	65.2	85.9
	2nd	# Seed	43	39	136	72	54	111
	"	Germ %	27.91	38.64	46.33	54.93	32.73	46.2
D 14-15	1st	# Seed	1345	1313	1423	1270	1478	1783
	"	Germ %	68.3	68.3	72.2	81.0	90.9	80.1
	2nd	# Seed	659	716	649	767	608	432
	"	Germ %	42.1	46.5	74.4	82.2	86.1	76.2
S 526	1st	# Seed	1917	1821	1600	1709	1469	1586
	"	Germ %	100+	89.5	79.3	77.7	78.8	93.3
	2nd	# Seed	198	163	347	167	442	248
	"	Germ %	64.14	78.53	78.96	75.31	62.50	83.81
G 506	1st	# Seed	2122	1776	1664	1835	2045	1930
	"	Germ %	10.7	56.2	58.7	85.6	87.1	80.6
	2nd	# Seed	167	339	448	390	622	355
	"	Germ %	2.35	44.41	69.3	69.39	84.6	100+
C 532	1st	# Seed	2071	2167	2001	1834	2155	1918
	"	Germ %	67.4	73.9	84.7	83.4	91.1	95.0
	2nd	# Seed	130	165	101	219	196	139
	"	Germ %	45.39	53.99	71.0	56.83	76.02	66.19
B 6-10	1st	# Seed	1859	1894	1924	1831	1678	1832
	"	Germ %	0	23.9	37.4	62.3	57.5	86.7
	2nd	# Seed	226	198	472	328	139	200
	"	Germ %	27.76	52.13	36.64	46.50	49.75	29.12
H 508	1st	# Seed	1269	841	435	271	488	648
	"	Germ %	62.0	91.7	83.1	70.8	90.1	91.2
	2nd	# Seed	389	699	1204	1018	1355	1193
	"	Germ %	96.5	29.12	89.0	91.4	94.2	95.7

Table 3

CONE STORAGE AND EXTRACTION STUDY

Large cone crops put pressure on extraction facilities. Several organizations produced cone crops far in excess of their extractory capacity. Cone storage then becomes more critical. Several methods of cone storage are being used; one commonly suggested is large bulk crates or boxes. Recently St. Regis compared the bulk storage method with the standard burlap sack system. Homer Gresham (The NC State Annual Report) collected two bushels of slash pine cones from each of several ramets of numerous clones. One bushel from each ramet was placed in a burlap bag and the other placed in a 20 bushel cone box. Eighty bushels of cones were collected and stored by each method.

The resulting and quite dramatic differences in seed yields from the two methods after storage to the first week of December are shown in Table 4. Cones stored in sacks had 30 percent greater seed yield and the required opening time was reduced by 40 percent. Homer reported that 5 percent of the cones in crates were case-hardened while virtually no case-hardening was observed among cones stored in sacks.

Processing the cones through the drying kilns and tumblers a second or third time sometimes provides meaningful increases in seed yield. The seed from follow-up runs is sometimes of lower quality, with lower germination percentages, but the increased overall yield of up to 15 percent can be of great value. (Virginia Division of Forestry study was 17.9 percent). Significant quantities of high-value seed can be lost if care is not taken in the cone storage and seed extraction.

COMPARISON OF YIELDS FROM CONES STORED IN BULK

AND BURLAP CONTAINERS BY ST. REGIS

NUMBER OF BUSHELS	TYPE OF CONTAINERS	TIME TO OPEN 1/	LBS. OF SEED PER BUSHEL
80	20 bu./crate	13 ½ hrs.	1.04
80	1 bu./bag	8 hrs.	1.35

1/ Extraction was done in their new seed plant.

Table 4

"FOREST INDUSTRY NURSERY REVIEW"

Ted W. Sweetland[1/]

Our general operation for the production of 1-0 loblolly pine seedlings is quite similar, I'm sure, to the operations of many of you in attendance here today.

The Woodlands Division of Continental Forest Industries, Hopewell, Virginia, operates the only industrial loblolly pine seedling Nursery in Virginia. The Nursery has been in production continously since the spring of 1959 when the first crop was sown. To date, twenty crops, of approximately twelve million seedlings each year, have been produced.

The Nursery is located on the south side of Route # 10, about 1½ miles east of Route # 1 near Chester, Virginia. The seventy-five acres of land, within the Nursery boundaries, are set aside as follows: twenty-two acres in permanent seed beds, forty-five acres in seed orchard, roads, fields, and offices, eight acres are in woodland. The seed bed area is divided into four 6 acre blocks. The site was selected because it contained suitable soils and water quality for Nursery management and because of its central location to the nine forest areas being operated by the Hopewell Woodlands District. Feel free to visit us after our Conference - please let me know if you are interested. Printed directions will be available and I will arrange to meet any visitors at the site on the day of your choosing.

Abstract.--The information which is assessed herein is more or less apparent with the Industrial Forest Tree Nurseryman in the Southeast United States and those of Federally or State owned operations.

Cooperation between industrial and public Nurseries over the years has always been of the highest order. The purpose for compiling these data is to describe more fully the place we, as Industrial Nurserymen, fill in our working situations.

1/ Nursery Superintendent, Continental Forest Industries, Hopewell, Virginia

DISCUSSION

From our company's standpoint a few points need to be mentioned, which are advantageous, and will need expansion:

1. We have built-in "family type" connections and close communications. With the advent of 2-way radio communications we augment our telephone seedling orders en route to other locations and projects.
2. Problems, which inevitably arise, are soon overcome since communication is so close.
3. We are not involved with an exchange of funds when seedlings are picked up at the Nursery.
4. Improved changes or changes made for the sake of better efficiency are speedily inaugurated.
5. Supply and pickups due to unusual weather can be adjusted rapidly. We can store seedlings for an area, if needed; and they can pick up the reserved lot again as conditions improve.
6. We do not have to supply various amounts of different species to a large number of consumers, some located in remote corners of the state.
7. Many problem-solving experiences are expedited on the spot because the chain-of-command is not lengthy.
8. Trade-offs of labor between the Nursery and planting crew are rather easily done with little lost time in the trade process.

Results of a questionnaire sent in mid-winter to a number of industrial Nurseries will be commented on at this time.

SUMMARY OF QUESTIONNAIRE

Questionnaire results and comments-seven industrial Nurseries contacted.

1

BALE OR BAG SEEDLINGS?

Five of seven Nurseries responded as baling seedlings.

This part of the Nursery operation is most probably predicated on the aspect of temperature control from lifting to field planting. Generally, those bagging seedlings can control the temperature, or keep cool, the bags from day of bagging to actual field planting.

All factors considered, the handling of seedlings in bales is preferred to maintain a healthy, transplantable seedling in transit or under varying conditions of storage.

2

PROMOTE GIVEAWAY SEEDLING?

Most Nurseries do not actually promote free seedlings.

Farm groups, science groups and tour groups receive attention in this regard. Our company honors requests on a first-come, first-serve basis and has made avaiable over 10 million free trees since our first production year in 1959.

3

DO YOUR UNITS OR AREAS EVER RUN OUT OF SEEDLINGS DUE TO NURSERY OPERATIONS?

Almost ½ of those Nurseries queried said "yes" to this question.

Surprising as it may seem, weather and a slow down in pulling of seedlings were equally to blame for this problem.

When one considers that such an occurrence would be remote, still it may often be the case that field plantings occur on such diverse sites versus an extremely wet Nursery site that the last million or so seedlings the Nurseryman has on hand will be on a difficult site from which to lift seedlings.

4

ARE YOU CENTRALLY LOCATED TO MOST OF YOUR PLANTING SITES?

All Nurserymen answered in the affirmative to this question.

Location of Nursery properties has this as a prime requisite for ease of control and to keep travel to a minimum for all areas or units.

5

IS THERE GREAT COMPETITION FOR LABOR BETWEEN YOUR OPERATION AND THE NEAREST PUBLIC NURSERY?

All Nurserymen answered "no" to this question.

Historically, industrial and public Nurseries have not been overly competitive in this area, mainly because equal work under similar conditions pays equal wages. Also, the very nature of the managers involved will preclude most "cut-throat" dealings in wages, pay scales, or hiring practices.

6

IS THE TEMPERATURE CONTROLLED FOR STORAGE OF YOUR SEEDLINGS BOTH AT THE NURSERY AND NEAR THE ACTUAL PLANTATION SITE?

Most answers received to this question were "no".

Some replies qualified their response on grounds that the Nursery controlled the temperature of baled or bagged seedlings, but that once out of the control of the Nursery no provisions were made to keep seedlings from heating or freezing. The same cooling unit will prevent either problem. Bagged seedlings are extremely susceptible to overheating especially if bags are crammed with too many seedlings. Bales will fare better even in excessively cold conditions but for outside storage should be covered with a minimum of protection - i.e., plastic, canvas, pine boughs and/or sheet insulation.

7

DOES YOUR TREE IMPROVEMENT PROGRAM MESH WELL WITH YOUR OVERALL OPERATIONS?

All respondents replied "yes" to this question.

Assuming that labor supplies and equipment for both orchards and Nursery work originate from the same base, this can be a happy blend of two highly related operations. In fact, in no other area of woodlands operations is there a better opportunity to exhibit cooperation. Oftentimes, the Nursery Supervisor is a breed of both operations either by longevity, training or both.

<u>8</u>

IS THE TREND UPWARD FOR NURSERY PRODUCTION?

Most replies were in the affirmative but only slightly. One Nursery commented that they were stabilized at a certain figure. I would assume that this would also be the case for at least some other Nurseries. Probably most cutting and site preparation schedules are fairly constant as to acreage needed yearly and it would follow that areas ready to receive seedlings yearly would remain constant. Also, most Nursery capacities remain constant due to an array of reasons; best known to each company and their policies.

<u>9</u>

The species grown most was far and away loblolly pine. Slash and Virginia Pine were a poor second with various water-complex oaks and sycamore a poor third.

An additional comment on loblolly will conclude my remarks on the questionnaire.

Loblolly pine is so unexcelled in its range, growth rate, logging acceptability and market demands that it is indisputably the champion economically useful species for our region. A substitute for this species would be difficult, if not impossible, to find.

CONCLUSIONS

Personally, I feel the prviate and public Nursery operations of all of our southern states works well - cooperation has been more than <u>adequate</u> and <u>we need each other</u>. With improved seed, improved techniques, mechanization and better communication, all Nurseries are entering the period of the eighties with greater optimism and know-how and with the greatest challenge to supply more and better seedlings than history can record to date. Additionally, the third century of our country's life and involvement in all phases of ecological needs require our expertise and full attention.

All of us here surely have a responsibility few of us dreamed of some years

back. It is through the interplay of ideas received here, at past meetings, as well as subsequent meetings down the road that we can continue to be, both public and private, the best and most knowledgeable Forest Tree Nurserymen our country has known.

HARDWOOD NURSERY MANAGEMENT - CLOSING THE INFORMATION GAP

Jake M. Stone 1/

Abstract.--The major concern of users of high quality hardwood seedlings is the high cost of production. This cost may be ten times that of pine seedlings. Efficient production of high quality seedlings requires increased knowledge in two areas. One, experience and initiative are needed to solve mechanical problems. Better seeders, better lifters, better packing and storage systems are all needed. Two, the greater need is to understand the fundamental physiological responses of hardwoods to cultural treatments beginning with seed production. When we learn the biological requirements necessary for consistent production of high quality hardwood seedlings, the mechanical problems will be easily solved.

INTRODUCTION

After operating for three years in blissful ignorance with neither total failure nor success, it became apparent that we really do not know enough about producing hardwood seedlings. Each year we have adjusted techniques to make the job easier or more efficient. None of these changes made a significant contribution to improving seedling quality. In our case, quality and size is synonymous. The problem is we do not grow enough seedlings large enough.

Improvement of equipment and facilities is important. Opportunities to capitalize on bright ideas should not be missed, but the real emphasis should be on learning what makes hardwoods grow or not grow. High speed harvesting of an inferior product is a futile exercise.

Preliminary results from our current hardwood nursery related research indicates:

1. Definite seedling response to various levels and sources of nitrogen fertilizers.

2. A suspected response to endomycorrhizal inoculation.

3. A possible response by sweetgum (*Liquidambar styraciflua*) to two hour night lighting.

4. Two herbicides, Treflan and Devrinol, are at least moderately effective in controlling weeds without noticable damage to hardwood seedlings.

1/ Supervisor, Management Services, Union Camp Corporation, Franklin, Virginia.

More research is needed in every area of nursery management. Priorities are difficult to determine. Everything needs to come first. Some questions I would like to have answered include:

1. Seedling Nutrition - Which fertilizer(s) should be used? How much is needed? When is it needed? What is the interaction with mycorrhizal fungi? What are the responses at various levels of irrigation or rainfall?

2. Seed Quality - How do we get the most out of wild seed while waiting for improved seed? Where do we go for seed or seedlings when local sources are not available? How should non-dormant seed be stored? How is physiological dormancy broken to enhance uniform germination?

3. Seedling Quality - How big is big enough? What is a balanced hardwood seedling? How can maximum growth and early hardening off be reconciled?

4. Pests: Diseases - What causes unexplained failures? Is fumigation essential for disease prevention? Does storage mold affect live tissue?

5. Pests: Weeds - Which herbicide should we try? What is its effect on seedlings, target plants, and soil organisms? Does it build up in the soil or carryover to subsequent crops?

NURSERY RESEARCH IN PROGRESS

In conjunction with our Woodlands Research Department, we have either initiated or are participating in several hardwood nursery research projects which should fill some of the information gap. Because the studies are in progress, hard data are not yet available, but there are observable responses.

Seed Quality

The observation that larger seedlings were usually produced from larger willow-water oak seed, led me to wonder if this is not the case with sweetgum. In cooperation with NCSU Hardwood Cooperative and the U. S. Forest Service, three sweetgum seed lots were separated into four size fractions each. Among the fractions size ranged from 144,000 seed to 81,000 seed/lb. There was a direct correlation between seed size and percent germination with the largest seed having the highest germination. The high and low germination was 95% and 43%, respectively.

Seedlings produced from these seed fractions are now being grown in a green house. Differences, if any, in seedling growth will be measured.

What is the practical implication if we get green house growth differences? By removing the poorest fraction of a given seed lot, uniformity of germination and subsequent seedling crop should be improved. Improved uniformity reduces the seedling cull factor. Low seedling density per unit of area is the factor that contributes the most to high seedling cost.

Seedling Nutrition

Sometimes it is more important to just get the job done than be overly concerned with efficiency. This type of situation prompted us to undertake a rather intensive fertilizer study. The study is in cooperation with Dr. C. B. Davey of NCSU and Mr. G. W. Bengtson of TVA.

The study measures the response of sweetgum and green ash (Fraxinus pennsylvanica) to seven sources of nitrogen fertilizers applied at three rates of elemental N. The sources are sulfur coated urea, 11% dissolution rate (SCU 11); sulfur coated urea, 24% dissolution rate (SCU 24); isobutylidene diurea (IBDU); ammonium nitrate; nitrate of soda; sulfate of ammonia; and urea. SCU 11, SCU 24, and IBDU are slow release fertilizers and were applied preplant only. The other sources were applied as a top dressing throughout the growing season. The rates of application are 200, 300 and 400 lb/ac of elemental N.

Differences in response to the various sources are pronounced. The poorest treatment appears to be nitrate of soda. The better treatments appear to be sulfate of ammonia and SCU 24. Both of the better treatments are better than the operational fertilization which is ammonium nitrate at the 400 lb N level.

Our intention is to both refine and expand this study. It will be expanded to measure responses of sycamore (Platanus occidentalis), and the willow-water oaks (Quercus phellos & nigra) to various sources and levels of N. It will likely be refined to measure response to timing of applications, and also measure response to combinations of slow release and soluble sources.

When all the data are analyzed, we should know what is best for us, and more importantly what is good enough. We have already concluded that the operational top dress applications can be changed from weekly to bi-weekly. The better treatments appear at least as effective at the 300 lb rate than does the operational treatment at the 400 lb. rate. If this proves to be so, an immediate benefit is a 25% reduction in the N fertilizer required.

Again in cooperation with NCSU, and Abbott Laboratories, we are involved in testing various levels of inoculum of the endomycorrhiza, Glomus faciculatus. Dramatic responses to this and other onoculations are not apparent at our nursery. The nursery soil has an inherently high level of phosphorous, which ranges above 90 lb/ac. The availability of phosphorus may be reducing or eliminating the seedlings' need for mycorrhizal infection.

The response of outplanted hardwood seedlings inoculated with endomycorrhiza may prove to be of much greater importance than nursery response. With the short rotations contemplated for intensively managed hardwood plantations, relatively small early gains in growth assume importance.

Pest Control

Union Camp recently joined the Auburn Weed Control Cooperative. During the current season, we are participating in the operational nursery herbicide study and herbicide screening tests.

The operational test is a post plant pre-emerge application of Treflan followed by a "piggy-back" application of Devrinol after germination is complete. Preliminary measurements show that this method is approximately 50% effective. The degree of control is not observable without measurement, and is not impressive until you consider that no weed control resulted in hand weeding requirements up to 180 man hours/ac each month.

The treatments were applied to sweetgum, sycamore and green ash. There are no observable negative effects to the seedlings. However, final measurements of growth and survival have not been made.

Photoperiod

Also in progress is a test measuring the response of sweetgum to night lighting at various levels of intensity for a two hour period around midnight each night throughout the growing season. Responses will be measured from levels ranging from a high of 40 foot candles down to zero foot candles artificial light. The observable response is not dramatic, but seedlings do appear slightly larger under the lights than the average operationally grown seedlings.

The practical value of this test will be determined by (1) the light intensity required to get increased growth, and (2) the presence or absence of a better alternative method of achieving the same results.

EQUIPMENT DEVELOPMENT

Fertilization

Based on an idea developed by the late Gerald Black of Weyerhaeuser, a granular fertilizer applicator was built that fertilizes three seed beds simultaneously. The agitating or tumbling bar within the applicator is hydraulically driven rather than ground driven. The hydraulic drive allows operation at ground speeds up to 6 mph. The production rate is approximately 5 ac/hr at 6 mph. This is at least a 75% reduction in application time from our single bed, ground drive application method.

Seedling Harvesting

Initially, hardwood seedlings were transported from the field to the packing house on a trailer. The seedlings were unloaded by hand and the trailer returned for another load. Either field labor came in with the trailer to unload, or the packing crew stopped packing to unload.

In late 1977, the trailer was replaced with large 3 sided pallet boxes, and a lift fork was installed on a farm tractor front-end loader. Pallet boxes are moved from the field to the packing house with the fork lift tractor. The fork lift places the full pallet box on a platform equipped with casters. The loaded pallet can then be moved by hand into storage or position on the packing line. Empty pallet boxes are returned to the field by the fork lift tractor.

The elimination of the unloading procedure paid for the additional equipment the first year of use.

HANDLING PINE SEEDLINGS

by

Hamlin L. Williston*

Abstract.--Major findings of studies are presented on ways to maximize survival of pine seedlings in the nursery, in cold storage, in transit, as well as on the planting site. Culling of seedlings is discussed, together with optimum and detrimental storage temperatures, humidity, packaging, pruning, storage duration, planting dates, and related requirements for optimum success with pine seedlings.

Keywords: Nursery, planting, pines, seedlings, cold storage.

Almost everyone is cost conscious today as they well should be. But are we penny wise and dollar foolish? A seedling worth a little more than a penny at the nursery has more than 10 cents invested in it by the time it is planted. Indeed, superior seedlings planted on heavily prepared sites may be worth 25 cents each. Many dead seedlings are being planted. When less than 250 to 300 well-distributed pine seedlings per acre survive, that acre must be replanted. It may be necessary to repeat the site preparation. And a years' growth on that acre has been lost. Here are some thoughts on how to increase field survival through improved handling.

HANDLING SEEDLINGS IN THE NURSERY

Several years ago I visited a nursery and found the floor of the packing shed littered with plantable seedlings. The 12 girls along the table appeared to do little other than position the seedlings for weighing and treatment with slurry. I heard the foreman say, "When you bundle 200,000 you are through for the day." I discussed this with the responsible assistant state forester, pointing out that every plantable seedling on the floor was worth a penny and that the labor was highly ineffective. His response was, "We can't pay enough to get good supervision and we have to give the girls some incentive to work." A good tree grower must first of all be a good people manager and must recognize that it is more important to be respected than loved.

State nurseries have almost entirely abandoned the grading of seedlings. Some industrial nurseries cull seedlings. Frankly, I want, and am willing to pay more for, seedlings that have been culled and counted at the nursery. No one can afford to plant seedlings that have a poor chance of survival nor can we permit tree planters to cull in the field--that is an invitation to waste seedlings and slow down production.

*Hamlin L. Williston is a Softwood Specialist, USDA Forest Service, Southeastern Area, Jackson, Mississippi.

COLD STORAGE

Temperature

Cold storage facilities are virtually mandatory today, both at the nursery and at field headquarters. Seedlings must not be lifted until they are dormant, to successfully withstand long term storage. The temperature in cold storage should not fluctuate. Variations in temperature result in condensation of water on the foliage or packing materials, forming favorable spots for mold development. The temperature should be maintained as close as possible at 28° to 34° F. (-2.2° to 1.1° C.). Temperatures above 36° F. (2.2° C.) are critical for mold development (Navratil 1973).

Some poor field performance has been attributed to loss of starch content in the tops and buds because of respiration while in cold storage. This problem indicates inadequate cooling (Hocking and Nyland 1971). After chilling requirements to break bud dormancy are satisfied, seedlings of many species become physiologically active in response to temperatures above 35.6° F. (2° C.) (Jenkinson 1975).

Humidity

Ideally the humidity should be maintained at 90 to 95 percent in cold storage to prevent unprotected seedlings from drying out. It helps to sprinkle water on the walls and floor. Another solution is to package the seedlings in moisture-proof film as in a K-P bag (Kraft-polyethylene).

Packaging

Packaging in Forest Service bales is still acceptable but is being phased out because of the high cost and shortage of sphagnum moss and because it is necessary to water the bales when not held in cold storage. K-P bags with and without moss or with the seedling roots dipped in a clay slurry have proven to be entirely satisfactory. These bags should be strapped with a stick in the rolled top to make them easier to handle. Bags that are strapped take only about two-thirds as much room as those that are unstrapped and enable you to increase cold storage capacity, which is often at a premium, by 50 percent.

Duration of Storage

Loblolly pine seedlings in K-P bags can be held in cold storage for 3 months without adverse effect on first-year survival (Williston 1965). But if they are stored in a warehouse for more than 4 weeks or after March 15, put a pound of wet moss in the package. Do not store them more than 8 weeks nor water the bags in the warehouse.

Forest Service bales packed with moss can also be held in cold storage for 3 months without special attention if the temperature is

held at 28° to 34° F. (-2.2° to 1.1° C.) and the humidity is 90 percent plus. Warehouse storage should be limited to 8 weeks during which time the seedlings should be watered every 2 or 3 days (Ursic 1956).

Freezing

Storage must protect seedlings from freezing as well as heating. Instances have been reported where loblolly and slash pine in North Carolina did not suffer from freezing at 20° F. (-6.7° C.) for 24 hours (Hodges 1961) or for 48 hours in Louisiana at the same temperature (Byrd and Peevy 1963), but in Tennessee, freezing for 36 hours and longer resulted in total mortality for both loblolly and shortleaf pine seedlings. In two studies (Garner and Dierauf 1974) a single, short period of freezing (2 and 3 days down to 12° and 14° F.) [-11° and -10° C.], followed by complete thawing before handling, did not reduce the survival of loblolly pine. However, in two other studies conducted by the same research team, storage at approximately 20° F. (-6.7° C.) for 1 month resulted in almost complete mortality.

Most of the evidence is anti-freezing. If the seedlings do freeze and the decision is to plant them, allow them to thaw before moving. Longleaf pine seedlings do not store well under any circumstances and should be planted within a day or two of lifting.

Brown (1977) has reported that the various tree species differ in their capacity to withstand below freezing temperatures. Trees that are not cold hardy can withstand temperatures a few degrees below freezing because ice must form to kill the cells. Trees that are cold hardy owe this capacity to three factors: a glycoprotein that binds the water in cells and keeps it from turning into ice; a special type of membrane that tends to keep ice out of the plant cells and also allows water to move out of the cells more quickly; and a "super cooling" phenomenon which tends to keep ice crystals from forming. Researchers are attempting to select hardy varieties within species and to cross them for cold hardiness. They are also identifying and applying chemicals that are capable of inducing cold hardiness.

TRANSPORTATION

A timber management assistant called me to say, "We just got a truck load of hot trees. What do we do?" I suspect that this is a situation that frequently goes unreported. There is no easy answer. Ursic (1961) determined that temperatures of 118° F. (47.8° C.) for 2 hours are lethal to loblolly pine seedlings. We have no reliable information on the effects of various temperature-time combinations lower than this.

If you do receive a load of hot trees, separate the hot bundles from the cool bundles. Check sample seedlings from deep within the hot bundles with a Rykerscope (if available) to determine whether or not they are still living. Otherwise hold the hot bundles in a cool place for at least

a week to see if the bark will begin to slip on the seedlings. Haste to plant hot trees results in waste. We learned the hard way from out-planting a rail car of hot trees.

Shipment in refrigerated trucks is the ideal means of preventing seedlings from heating, but a cheaper alternative is to use slat sided trucks with a tarpaulin top (Balmer and Williston 1974). The slat sides allow some air circulation and can accommodate cross slats for stickers, providing additional circulation. In warm weather, haul seedlings at night when possible.

HANDLING AT THE PLANTING SITE

Slurry

When we first began to get slurry-treated seedlings, one of my foremen proudly took me over to an old-fashioned washtub full of water. "See! I wash the mud off all the roots," he said, "because the men don't like to get their hands messed up when it is cold." The slurry in this case was so thick that the seedlings stuck together, making separation difficult.

Pruning

On another planting chance, the foreman pulled out some large scissors and said, "The roots of these seedlings are too long so I cut them all back to six inches." Seedlings with 6-inch (15.2 cm.) roots will survive and grow well. Indeed, seedlings with 4-inch (10.2 cm.) roots will survive (Ursic 1963). In Virginia, Dierauf and Garner (1978) found that pruning the roots of loblolly pine seedlings to 3 inches (7.6 cm.) reduced survival by 6 to 8 percent.

Studies on the correct top:root ratio have generally been inconclusive, but the best seedlings in my opinion have a balanced top:root ratio. Some characteristics of ideal planting stock are given in table 1 (Williston 1974). Extra large seedlings are hard to plant and will wind whip. I cite these two incidents to point out that when seedlings are shipped from the nursery they should be in an easy-to-plant condition.

Table 1.--Ideal Planting stock[1/]

Species	Planting Site	Top Length	Minimum diameter of stem
		Inches	
Loblolly	Moist	9-12	3/16
	Dry	5-9	1/8
Shortleaf	Moist	8-12	3/16
	Dry	4-7	1/8
Slash	Moist	10-14	3/16
	Dry	6-9	1/8

1/ Roots: 7 to 8 inches (213.3 to 243.8 cm.).

Carriers

On the second planting job mentioned, the men carried the seedlings in buckets. We have found that the use of planting bags increased production by approximately 25 percent and was less fatiguing because it reduced the number of "stoops." Keep a handful of wet sphagnum moss or granulated peat in the bottom of the bag Take care not to stuff too many seedlings into the bag because it is easy to strip off rootlets as the seedlings are removed from the bag.

Timing

Last winter a woodlands manager called me and said, "We lost 1,000 acres (404.7 ha.) that we planted in January. Dug up a number of them and they were correctly planted. Other seedlings from the same shipment planted later lived. What is your explanation?" I asked him if he had had a week or 10 days immediately following planting in which it was cold enough for the ground to freeze. "Affirmative! How did you know?" Twenty years ago I lost 20,000 seedlings heeled in a bed of sand. The answer was desiccation. So if an extended "blue norther" is forecast in areas where the ground freezes, keep the seedlings in storage.

Seedlings planted in the coldest part of the winter, when the soil is too cold for root growth, are merely stored in the ground. Chances of a disastrous cold spell occurring are greatly increased by planting in December and early January. In the Oxford, Mississippi area, first year survival of loblolly pine over a 10-year period increased progressively for planting in December (72 percent), January (74 percent), and February (78 percent) (Ursic, Williston, and Burns 1966). Survival and growth of March and April plantings consistently ranked the highest. Nurseries with large cold storage facilities can continue to lift during the dormant season and still gear seedling delivery times to those landowners desirous of planting late to improve survival.

You have probably all heard stories similar to the following. A tree planter said, "A dozen seedlings lay on the floor board of my truck for a week. I planted them in my yard and 11 of them lived." Don't you believe it. Pine seedlings are extremely sensitive to drying of the roots even though they can be surprisingly tough. We really know very little about what Wakeley called physiologic quality.

CONCLUSION

Seedlings take constant care through every step of the nursery, shipping, and planting operations to insure a living tree. A nurseryman's objective should be to produce a tree that is living at the end of the first growing season. (Second-year mortality is usually slight). True, it is not all in your hands, but the field force will just naturally take greater pains with a quality product. If there is one characteristic that distinguishes the true professional from the would-be professional, it is constant attention to quality control.

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PROBLEMS WITH SEEDLING DORMANCY AND FREEZING

T. A. Dierauf

Abstract

Muriate of Potash and Seedling Dormancy - application of muriate of potash (KCl) containing the equivalent of 100 and 200 pounds per acre of K_2O on September 15 reduced survival of seedlings lifted on November 1, November 15, and December 1 and placed in cold storage for two weeks before planting.

Freezing in Storage - storage of dormant seedlings at 20 degrees Farenheit for one month caused complete mortality in 1972 and 95 percent mortality in 1973. However, in 1978 dormant seedlings that stayed frozen in unheated buildings for approximately two months survived well.

1976-77 Freeze Damage in the Seedbeds - seedlings with tops severely damaged when the soil stayed frozen for about seven weeks survived only about half as well as seedlings that had no top damage.

Key Words: Seedling dormancy, Freeze damage, Muriate of Potash, Storage

The three studies I will talk about this morning are concerned with cold weather. The past two winters in Virginia have been record breakers for cold weather, so cold weather has been on our minds, but even in normal winters, cold weather is a problem in Virginia for at least four reasons:

1. Seedbeds freeze up so seedlings can't be lifted

2. The soil at the planting site freezes so seedlings can't be planted

3. Seedlings stored in barns and open sheds commonly freeze in the packages

4. Once planted, seedlings take a beating when the ground is frozen so the roots cannot take up water.

Ideally, we would like to wait until most of the severe cold weather is over, and plant from about the middle of February through March. But we can't get the job done in this short period of time, so in practice we have to start much earlier, and usually are still planting in May.

MURIATE OF POTASH AND SEEDLING DORMANCY

Introduction

One way to avoid some of the problems of severe, freezing weather would

be to start planting in the fall. We normally start planting about December 1, but from the weather standpoint, November would be a good month to plant. In a normal season, the soil seldom freezes in November, and soil moisture is usually adequate. At the 1976 Southeastern Area Nurserymen's Conference, two years ago, I discussed our tests of October and November planting of loblolly pine (Pinus taeda L.) using seedlings that had not yet hardened off or become dormant (Dierauf 1976). You may remember that survival was satisfactory for November 1 and November 15 plantings when the seedlings were planted within a day of lifting. But after storage for two weeks survival was not satisfactory. The ability to withstand storage increases through November, and by December 1 our seedlings are fully dormant and store satisfactorily.

If we could find some way to hasten dormancy, to move up the date when seedlings become fully dormant, we could safely start planting earlier than we do now. We had been hearing for several years about the favorable effect muriate of potash has on hastening dormancy, so in the fall of 1976 we decided to test potash applications in our nursery at New Kent.

Procedure

We talked with Dr. Chuck Davey about what rates of muriate of potash (KCl) to apply and on what dates. Soil tests indicated we already had about 100 pounds per acre of K_2O in the soil, which Chuck said was about normal for nursery soils at this time of year. He suggested rates of muriate of potash that would supply 0, 100, and 200 pounds per acre of K_2O. We also tried two different rates of application, September 15 (the usual date of application) and October 15. This provided six different KCl treatments. Based on our earlier work with fall planting, we planned on three different lifting dates: November 1, November 15 and December 1. This made a total of six KCl treatments x three lifting dates = 18 plots per seedbed block. We installed three seedbed blocks in different parts of the nursery. Each plot was four feet long, so a seedbed block was 72 feet long.

On November 1, when it was time for the first lifting, we could see no differences among the KCl treatments. Foliage color was uniform over all plots. We talked to Chuck about whether we should go ahead with the field planting. We finally decided to lift and plant only the September 15 KCl applications.

The main reason for this decision was that the fall of 1976 was unusually cold in Virginia. Average minimum temperature was 1.3, 4.9, and 6.3 degrees lower than normal in September, October and November respectively. In the latter half of October the temperature fell below freezing on eight days at nearby Byrd Field, and in November the temperature fell below freezing on all but nine days, including four days below 20 degrees. We decided that the October 15 application of KCl probably had had little time to affect dormancy, and so dropped it.

For each of the lifting dates we made an immediate planting, either the same day or the day after lifting, and also placed seedlings in cold storage for two weeks before planting. The planting part of the study was, therefore, similar to the fall planting studies we had been installing for several years.

We wanted to find out whether KCl applications would improve the storability of seedlings lifted in November.

Weather After Planting

I have already mentioned that the average minimum temperature in November was 6.3 degrees below normal. December was also unusually cold in Virginia, and January was the coldest on record. The effect on survival of seedlings planted prior to January was severe.

Results

We tallied survival in the spring of 1978, after the seedlings had been through the second winter in the field. Survival was unsatisfactory, even for seedlings planted within a day of lifting, but the effect of two weeks of storage was similar to what we found in the past (Table 1). In Table 1, KCl treatments have been combined. The interaction between lifting date and storage is significant way beyond the .005 level.

Table 1. Survival percent after one year, KCl treatments combined

Date Lifted	Planted Immediately	Stored 2 Weeks
November 1	53.3	18.9
November 15	45.6	30.0
December 1	45.0	55.0

The application of KCl did not improve the capacity to withstand storage, in fact, the reverse was true: seedlings receiving KCl did not survive as well after two weeks in storage, and seedlings receiving the equivalent of 200 pounds of K_2O did not survive as well as seedlings receiving the equivalent of 100 pounds of K_2O (Table 2). When stored seedlings were analized separately, the effect of KCl was significant at the .01 level.

Table 2. Survival percent after one year, for seedlings stored two weeks

Date	K_2O Applications		
Lifted	0	100	200
November 1	23.3	20.0	13.3
November 15	36.7	28.3	25.0
December 1	61.7	51.7	51.7

Our experience with seedling survival studies is that when first year survival is high, very little additional mortality will occur the second year. But, when first year survival is low, as in this study, we sometimes get considerable additional mortality the second year. It is unlikely, however, that the relationships will change much.

EFFECT OF FREEZING IN STORAGE

Introduction

It is common practice in Virginia for landowners to store seedlings in unheated barns and sheds between the time we deliver the seedlings and the time they are planted. Seedlings commonly freeze in the packages. In 1970 and 1971 we conducted some tests in which fully dormant seedlings, in packages, were allowed to freeze during short periods (two to three days duration) of unusually cold weather when the temperature ranged from the low teens down to zero degrees Farenheit. Survival was not reduced by freezing for such short periods (Garner and Dierauf, 1974). Other people, in earlier tests further south, reported quite different results. Hodges (1961) reported 99 percent mortality of loblolly seedlings after being frozen at 20 degrees Farenheit for 48 hours. Bean (1963) reported complete mortality of loblolly seedlings after being frozen at 18 degrees Farenheit for 36 hours. Byrd (1963) got results more like ours: storing loblolly seedlings at 20 degrees Farenheit, he reported 96 percent survival after 48 hours, but only 50 percent after one week, and two percent after two weeks.

Tests of Frozen Storage

Based on our own encouraging results for short term freezing, and the possibility that loblolly in Virginia might be genetically better adapted to withstand freezing than loblolly further south, we decided to test long term frozen storage of loblolly seedlings, as is successfully done with northern species of pine and spruce. The only facility we had available was a seed storage room maintained at a constant temperature of 20 degrees Farenheit. A temperature in the upper 20's would have been preferred.

Tests were installed in both 1972 and 1973. Seedlings were lifted on March 9 for the 1972 test and February 22 for the 1973 test. Seedlings were graded to remove under-sized seedlings, root dipped in a kaolin clay slurry, and put up in standard 1,000 seedling packages. Six packages were placed in cold storage the same day the seedlings were lifted, and after a week three of the packages were removed from cold storage and placed in the seed storage room at 20 degrees Farenheit. Thus, seedlings were not immediately frozen, but were first placed in a conventional cold storage facility for a week. There were six treatments: planting after one, two and three months of storage, comparing conventional cold storage with frozen storage. The results can be stated briefly. Frozen storage didn't work. In 1972 all of the frozen seedlings died. In 1973, five percent of the seedlings survived after one month of frozen storage, but all seedlings died after two and three months storage.

Inadvertent Long Term Freezing

Based on these tests of frozen storage, we concluded that loblolly pine in Virginia cannot tolerate extended periods of freezing. However, this past winter, 1977-78, was also unusually cold and presented another opportunity to test extended freezing, but this time at temperatures which fluctuated with outdoor temperatures, rather than being maintained at a constant 20 degrees Farenheit. Westvaco and Georgia Pacific each had a large number of seedlings in storage that stayed frozen for most of January and February.

Georgia Pacific received their trees from our New Kent Nursery on December 21 and stored them in a brick building open on one end. Westvaco received their seedlings from the same nursery on January 6 and stored them in a log tobacco barn. The ground stayed frozen and planting was impossible until March. Both companies decided not to plant their seedlings, but gave us some of the seedlings for testing.

We obtained five packages (1,000 seedlings each) from each company and randomly selected one seedling from each of the twenty 50-seedling bundles in each package. This gave us a sample of 100 seedlings from each company. We took a similar 100 seedling sample from some freshly lifted seedlings. These seedlings were planted on March 22, in five blocks of 20 seedling rows. Much to our surprise, these seedlings survived very well. On July 19, half way through the first summer, all of the Georgia Pacific seedlings, 98 of the check seedlings, and 97 of the Westvaco seedlings were alive, and most of them were growing vigorously.

Discussion

These tests of the effect of extended periods of freezing raise some puzzling questions. Is there a difference between extended storage at artificially maintained constant temperatures and naturally fluctuating temperatures? In the 1972 and 1973 tests at a constant temperature of 20 degrees, mortality was almost complete after one month of storage. In the 1978 test, after two months of storage at fluctuating temperatures that were cold enough that the seedlings stayed frozen, practically all seedlings survived. Or are the differences in results due to seedling differences? Are some seedling crops, from the same nursery, better able to withstand freezing than others? In all tests, seedlings were lifted well after the time when they become fully dormant, so dormancy should not have been a factor, unless there are differences in the degree of dormancy from year to year.

1976-77 WINTER DAMAGE IN THE SEEDBEDS

I have already mentioned the unusually cold weather we had in Virginia during the fall and winter of 1976-77. January was especially severe. The ground froze to record depths in many parts of Virginia. At our New Kent Nursery there was a period of seven weeks when seedlings could not be lifted because of frozen ground. At our Augusta Nursery the frozen period was even longer. Browning of loblolly seedling tops began in January and became progressively worse through February and into March, when it finally stabilized. The damage was so bad at Augusta that we decided to plow under the entire loblolly crop. At New Kent the damage was much less severe and we went ahead and sold the seedlings. We reported on the extent of damage to loblolly seedlings at New Kent (Dierauf and Olinger, 1977). We concluded that the damage was caused primarily by desiccation rather than outright cold damage.

We planted 100 each undamaged, moderately damaged, (less than one-third of top killed), and severely damaged (more than one-third of top killed) seedlings on March 2. The seedlings were lifted from 50 different locations, taking two seedlings of each damage class at each nursery location.

Survival was tallied this past spring, after the seedlings had been

through the second winter (Table 3).

Survival was not good even for the undamaged seedlings, but the severely damaged seedlings survived less than half as well. The spring and summer of 1977 were dry. Between the winter cold and the spring and summer droughts, the 1976-77 season was the worst for seedling survival we have had in Virginia in a long time. Had the growing season been more favorable, the damaged seedlings might have fared better.

Table 3. Survival percent after one year

No Damage	66
Moderate Damage	58
Severe Damage	32

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BANDOLEERED CONTAINERS FOR AUTOMATIC TRANSPLANTER SYSTEMS

H. L. Brewer[1/]

Abstract.--Much work has been done on developing seedling containers. The job that a container must do has been well analyzed (Kinghorn, 1974) and many containers have been developed. Sometimes the container has been developed with minimum thought as to how it will fit into a completely automated system, thus, possibly restricting the degree to which transplanting systems could be automated. This is not always the case, however (Huang, 1973).

In working with establishment of grasses in pastures and rangelands, I thought that if a completely mechanized method of transplanting could be developed, then costs might be reduced enough so that transplanting could be a viable alternative to seeding. It was from this background that I developed the bandoleer concept of containers (Brewer, 1978). Cells connected together in a flexible string (bandoleer) might ease the mechanization process (Fig. 1).

Dr. James Barnett, USDA Forest Service at Pineville, LA, is evaluating the use of the containers in growing tree seedlings. If these experiments are successful, then the removal of the plug from the container just prior to planting should allow maximum freedom for the roots to grow uninhibited into the surrounding soil (Fig. 2).

Additional keywords: Seedlings, reforestation, stand establishment, grasses.

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Fig. 2. Plug is removed from container just before planting.

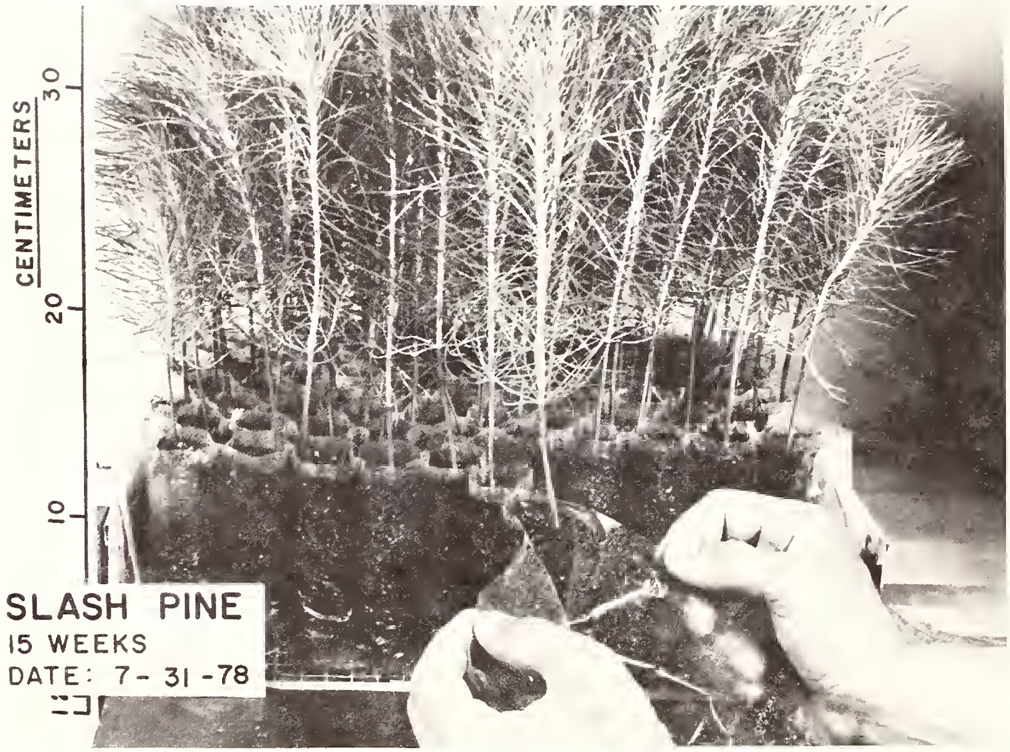

Fig. 1. Seedlings raised in 1 mil polyethylene cells formed into a bandoleer.

CONTAINER SEEDLING PRODUCTION AT MT. SOPRIS NURSERY

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INTRODUCTION

Containerized seedlings are a relatively new phase of nursery production all over the United States. Our greenhouse facilities at Mt. Sopris Nursery are only 1½ years old although the nursery has operated over 15 years. We are therefore still learning the culture of container stock but I feel that our facility is representative of many western greenhouse operations.

Our greenhouse was built in response to the current effort to eliminate the "reforestation backlog" in the Western States. The Central Rocky Mountain Region has over 325,000 acres of national Forest land to be aforested or reforested based on a recent inventory. This translates to over 130 million seedlings using planting density of 400 trees per acre. We have been given 10 years to alleviate this backlog ending in 1984. Considering that our bareroot seedling production requires from 2-3 years and that our annual production at Mt. Sopris Nursery was around 4 million trees, you can appreciate our dilemma. So the decision was made to build a greenhouse to supplement the bareroot program and provide a rapid means of producing stock for the reforestation backlog.

MT. SOPRIS GREENHOUSE FACILITY

We use two different size containers or cells in our greenhouse, one of 10 cu. in. capacity and another of 6 cu. in. Both types of containers are produced by Ray Leach and are made of soft plastic and bullet-shaped and are interchangeable in a hard plastic rack. The 1 ft. x 2 ft. rack holds 98 10 cu. in. cells or 200 of the 6 cu. in. size. We prefer this type of container because they are reuseable and the removeable cells allow culling and consolidation eliminating wasted bench space.

Our greenhouse is a metal frame fiberglass-covered structure containing 9,264 sq. ft. of useable table space out of a total 11,500 sq. ft. or 81% space efficiency. This converts to 926,000 seedlings of the 6 cu. in. size or 454,000 of the larger 10 cu. in. size. The seedling trays rest on 4 ft. high tables permitting good air circulation beneath the containers. These raised tables promote air pruning of seedling roots and heating from below provides warm soil temperatures.

We produce two crops of container seedlings each year, one in the spring and one in the fall (Figure 1). The early crop is sown around the first of March and remains in the greenhouse until the end of July. By this date, the seedlings should complete the desired top growth and are transferred to the shadehouse. The second crop is sown in July and remains

in the greenhouse through the winter. These seedlings finish their "hardening-off" in the greenhouse are transferred to the greenhouse late in the winter. Container seedlings are usually planted in the spring although late-summer and fall plantings are becoming common.

Because the majority of the reforestation backlog is Engelmann spruce (Picea engelmannii Parry), we are emphasizing that species in our greenhouse. Engelmann spruce requires three years in the field so our 6-month container seedlings represent a considerable savings in time alone. We have produced a small quantity cf lodgepole pine (Pinus contorta var. latifolia Engelm.), ponderosa pine (P. ponderosa var. scopulorum Engelm.) and Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Granco.

LOADING THE GREENHOUSE

A typical rotation begins with the preparation of the potting mix which consists of 50% acid peat moss and 50% coarse vermiculite. These ingredients are mixed together in a large rotary mixer along with a small amount of water. The resultant potting mix is coarse textured for good aeration and leaching, has excellent water retention, a slightly acid reaction of 5.0 - 5.5 and is essentially sterile. This potting mix is moved by conveyor to the loading table where the containers are filled.

Our homemade loader contains a motor-driven cam which shakes the containers while they are being filled; this eliminates air pockets within the containers. The filled containers are then tamped to compress the potting soil and provide space for the seed. The seeding operation utilizes a commercially-made shutter box which contains a number of holes corresponding to the container tray and a moveable shutter with offset holes. The prescribed number of seeds fall into the holes on the shutter and the seed drops into the containers when the shutter is moved over the lower holes. This system is reasonably precise and three seeders can keep up with the rest of the process. We usually seed from 2-6 seeds per cell to minimize empty containers. The seed is covered with a thin layer of white perlite which serves to keep the seed moist and reflects excess heat while providing easy penetration for the emerging seedlings. Completed trays are carried to the greenhouse by a Cushman scooter where they are loaded onto the conveyor which takes them to the tables.

GREENHOUSE GROWTH PERIOD

The growth period begins with the first irrigation of the fully loaded greenhouse. The germinating seedlings require frequent irrigation and emergence is usually complete in 3-4 weeks. The seedlings are thinned to one per cell and all empty cells are removed from the trays and replaced with containers with seedlings. This operation is time-consuming but assures a full greenhouse.

If the number of empty trays exceeds 5%, they are resowed after removing the perlite and ungerminated seed with a shop vacuum.

After the germination period is complete, the seedlings enter the exponential growth phase, so named because of the rapid height growth which occurs. Seedlings are forced to their maximum potential growth during this period by supplying all their biological requirements. The object is to minimize all ecological limiting factors through environmental modification. Day and night temperatures are kept within 2° F of the optimum for the species. Plant moisture stress is minimized through frequent fertigation, a termed we coined to describe simultaneous irrigation and fertilization. Carbon dioxide is generated during early morning hours to stimulate photosynthetic production. Vegetative growth is promoted through intermittent bursts of red light throughout the night.

Our fertilization formulas were developed by Dr. Tinus of the Rocky Mountain Forest and Range Experiment Station and are scientifically calibrated to provide exactly what rapidly growing conifers require (Figure 2). All 13 chemical elements are supplied to the natural irrigation water which is simultaneously buffered to ph. 5.5. While seedlings are in the exponential growth phase they receive a high nitrogen macronutrient solution (S.S. #1) and micronutrient solution (S.S. #2) which promotes vegetative top growth. After they have been moved to the shadehouse, they are switched to a low nitrogen-high phosphorus formula (S.S. #3), along with micronutrients.

The fertilizer solutions are mixed in 200 1. plastic tanks and then injected into the water system using a mechanical injector. The seedlings are fertigated often enough to maintain the plant moisture stress below 13 bars of tension; a pressure chamber helps to monitor plant moisture stress. We always fertigate long enough to adequately leach through the containers to prevent harmful chemical buildup. The fertigation "catch" solution is regularly tested for ph and salt concentration to assure that the fertilizer injectors are working properly.

The exponential growth period usually lasts for about 3 months at which time the seedlings have reached their prescribed height. They are graded to certain height standrads and moved to the shadehouse via conveyors.

SHADEHOUSE GROWTH PERIOD

The shadehouse growth period is designed to harden-off the seedling foliage and induce bud set. Fertigation and partial shading are the only environmental conditions we can alter during this period. The fertilizer recipe is changed to the low nitrogen-high phosphorus solution to promote root and caliper growth. The cool night temperatures at our elevation also promote dormancy.

Most seedlings are ready for outplanting after 4-6 weeks in the shadehouse even though they are not completely dormant. If they are not going to be planted immediately they will be held over in the shadehouse to the following spring. Container seedlings are usually shipped in refrigerated trucks to reduce stress during transport.

PROBLEMS IN CONTAINER SEEDLING PRODUCTION

The accelerated growth of container seedlings leads to some interesting problems. A greenhouse is a very fine-tuned instrument and the elaborate monitoring equipment is far from trouble-free. Rapidly growing greenhouse seedlings are quite succulent and susceptible to injury. In a greenhouse problems happen quickly and tender seedlings can be damaged in a very short time.

Disease organisms thrive under warm moist greenhouse conditions. Even though precautions are taken to exclude diseases, it is impossible to do so completely. In our greenhouse we have had no serious problems yet. Two fungi has caused some damage, however, Botrytis cineria causes a foliage blight and will eventually lead to a stem-girdling canker. Fusarium spp. causes a cortical root rot which kills seedlings during the cotyledon stage. If these diseases are controlled by rapid detection, roguing, fungicide application and environmental modification they do not lead to serious losses.

Equipment failure is possible at any time although most critical during the winter. A backup diesel generator protects against power failure and an alarm system will alert personnel of radical changes in environmental conditions. Our most serious problem to date involved our cooling vent which stuck about 4" inches open one night. That night the temperature dropped to around 0^{o} F and the row of seedlings nearest the vent suffered foliage burn. Luckily, the buds were not killed and most of the seedlings recovered.

Sometimes we are our own worst enemies. In May of this year our greenhouse crop of Engelmann spruce was in the cotyledon state and we noticed that our field crop of spruce had broken bud and started top growth. We reasoned, therefore, that daylengths were long enough so that we could save some energy and shut off the supplemental night lights in the greenhouse. A few weeks later we noticed that some of the seedlings had set terminal buds. Realizing our mistake, we turned the lights back on and those seedlings eventually began to grow again but we had lost about a months growth in the meantime. The moral is do not tamper with a well-running system.

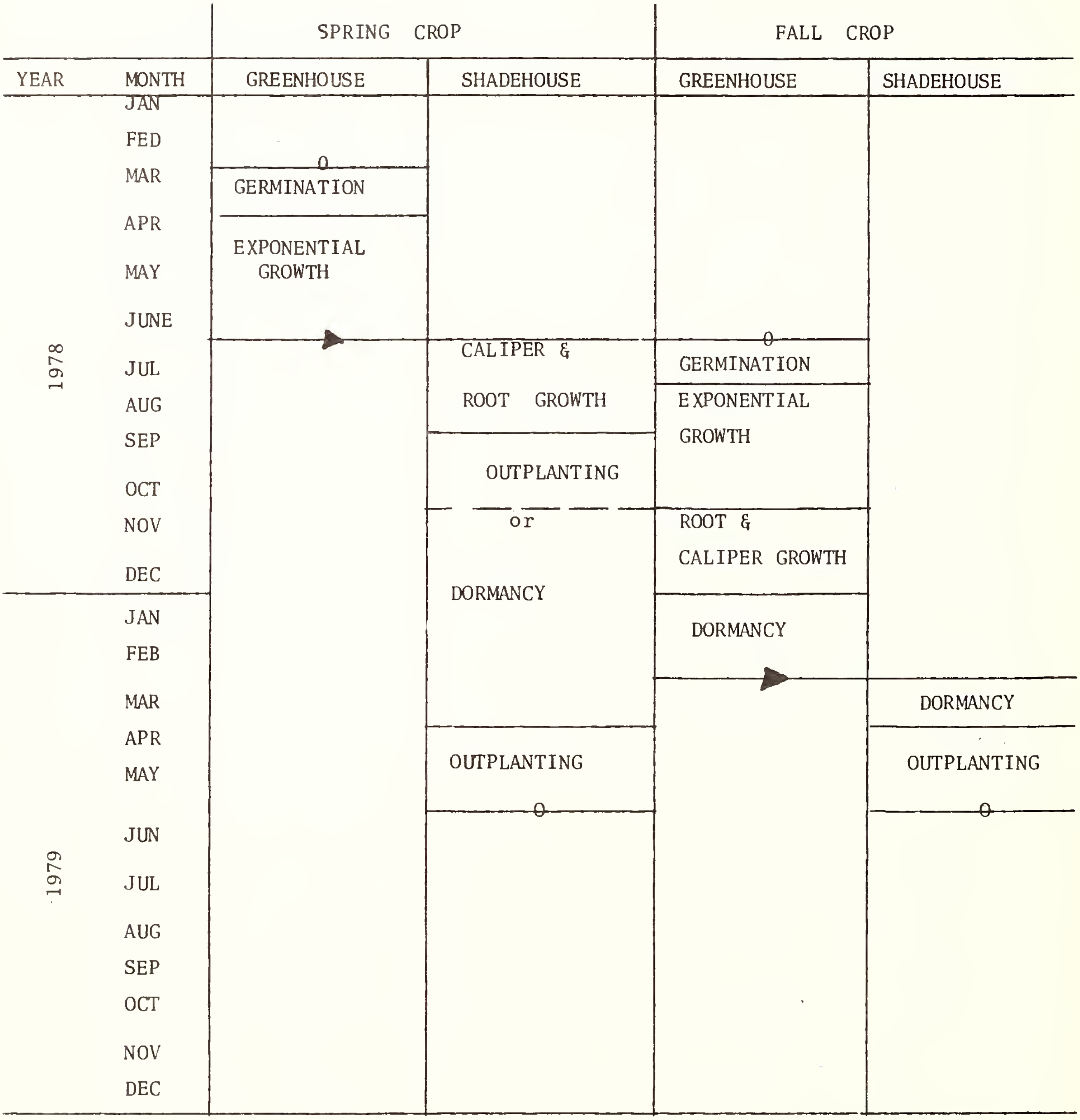
COMPARING CONTAINER AND BAREROOT SEEDLINGS

At our nursery all our bareroot stock is 2-0 or 3-0 in age whereas we can produce comparable container seedlings in 6 months. This quick growth is the most obvious benefit of a greenhouse system because it is more sensitive to changing reforestation priorities. Biologically, container seedlings suffer less transplant shock during outplanting because the roots never lose contact with the potting soil. Tubelings can be planted almost all year long except during spring shoot expansion when the succelent tops can be easily damaged. Storage on the planting site does not usually require refrigeration if the seedlings are kept moist. An additional benefit is that it is almost impossible to misplant a tubeling although it has been done.

Container seedlings are not without disadvantages. At our present prices, they cost twice as much as bareroot seedlings. The most serious problem is the increased handling and greater space required during transport and at the planting site. Shipping requires 5 times as much space and the heavy bulky trays are difficult for planters to handle. At the present time, we are having a hard time getting the containers returned promptly from the field. Tray breakage and loss always occurs to some degree.

The determining factor in the container vs. bareroot seedling comparison will be in the outplanting success. We currently have studies underway and have plans for several others. Initial results show comparable survival between the 2 types of stock but increased shoot growth for container seedlings. Outplanting trials must encompass the entire range of site conditions as one type of seedling may outperform the other in certain situations. I personally feel that container seedlings are simply another reforestation tool and will add a much needed flexibility to most western planting programs.

CONTAINER SEEDLINGS
TWO-CROP ROTATION



THE BEDHOUSE: ANOTHER OPTION FOR NURSERYMEN

By

Richard W. Tinus[1/]

Abstract - Bedhouses provide a degree of environmental control intermediate between outdoor bare-root beds and greenhouse container facilities. At the Coeur d'Alene nursery in Idaho an experimental bedhouse produced 160 ponderosa pine or 260 western larch per m^2 (15 and 24 per ft^2) that met 1-0 grade standards, whereas no pine and only 85 usable larch per m^2 (8 per ft^2) were produced outdoors.

INTRODUCTION

At present, there are two widely used systems for growing tree seedlings. Bare-root nursery stock is produced in outdoor beds normally for 1 year in the South, 2 years in the Pacific Northwest, and up to 5 years on the Northern Plains. Greenhouse container stock may be produced in 4 months or less, but is usually more expensive than bare-root stock f.o.b. nursery. Intermediate between the two is the bedhouse system developed in Scandinavia and apparently quite successful there (Bergman and Leskinen 1964).

In a bedhouse, bare-root stock is raised under a cover that provides a degree of climate control intermediate between the open field and the fully controlled container greenhouse. The objective is to lengthen the growing season by seeding up to 3 months earlier than outdoors. To do so requires a transparent cover and at least enough heat to maintain minimum growing temperatures. Cooling is usually controlled manually by opening large doors at either end or rolling up the sides part way. The doors or sides could be opened and closed by electric motors controlled by thermostats. When night temperatures are no longer cold, the cover and sometimes the whole bedhouse is removed. Thereafter, the beds are treated the same as any other outdoor beds.

Phipps (1969, 1973) tested bedhouses in Michigan and found they increased germination and seedling growth rates. Weyerhaeuser Corporation experimented with bedhouses in markedly different climates at Aurora and Klamath Falls, Oregon (Cowles 1976). In both places they produced 1-0 seedlings that met grade standards for 2-0 seedlings. Their success was attributed to considerable lengthening of the growing season and maintaining exponential growth of the seedlings. To do so required a minimum temperature of about 10°C (50°F).

Stein[2/] studied growth of seedlings in a bedhouse at the Bend Nursery in Oregon, and succeeded in producing 1-0 stock of several species that met grade standards.

[1/] Principal Plant Physiologist, USDA Forest Service Shelterbelt Laboratory, Bottineau, North Dakota.

[2/] Stein, William I., 1977. Principal Plant Ecologist, Pacific Northwest Forest and Range Exp. Stn., Corvallis, Ore., personal communication.

In 1976, Missoula Equipment Development Center was asked to evaluate bedhouses at U.S. Forest Service nurseries at Coeur d'Alene and Lucky Peak in Idaho. Realizing that it was primarily biological research rather than equipment development, they asked me to conduct the study.

MATERIALS AND METHODS

At the Coeur d'Alene Nursery a 7 x 29 m (22 x 96 foot) tubular steel framed quonset was erected and covered with 2 layers of polyethylene. The doors at each end were made as large as possible for good ventilation and for driving tractors through. Heat was provided by a propane-fired unit heater connected to a perforated polyethylene tube on the ground along one side which distributed warm air evenly throughout the house. Temperature and humidity at ground level were monitored with a hygrothermograph. A recording thermograph measured soil temperature at 1, 12, and 24 cm (1/2, 5, 10 inch) depths. Dial gage thermometers were used to spot check temperatures in different parts of the bedhouse. Soil samples were taken at several locations within the seedbeds.

The bedhouse could hold 4 beds 29 m (96 feet) long, but for the initial test only 2 beds 18 m (60 feet) long were laid out in its center. Similar beds were prepared nearby for the outdoor comparison or control, but were far enough away so they were not affected appreciably by the shadow or wind perturbation of the greenhouse. Both the bedhouse and control were on soil having a similar history with respect to cropping, fertilization, fumigation, and pesticide treatment. Control and bedhouse areas were treated the same with respect to fumigation, fertilization, and pesticide treatment during the study.

Ponderosa pine and western larch were the test species, because they can occasionally, but not reliably, be produced outdoors as 1-0 seedlings.

For each species, two seed sources were used representing as wide a difference in growth rate as possible. The sources were chosen so there would be appropriate planting sites for them in the spring of 1978.

The bedhouse was sown March 3 at a rate calculated to yield 270 pine and 320 larch per m^2 (25 and 30 ft^2). The bedhouse was maintained at or above 21°C (50°F). The doors were opened for cooling whenever the temperature reached 32 C° (90°F). The outdoor beds were sown May 10; the usual time for sowing outdoor beds at Coeur d'Alene.

The cover was removed July 22--more than a month later than planned. This was the first occasion in many weeks that the wind was not blowing. No damage was done, however, because the greenhouse never overheated.

Each month eight seedlings of each seed source were lifted and their height and root collar diameter measured. These seedlings were then pressed and mounted as herbarium specimens.

On November 15 the seedlings were lifted and graded according to nursery standards: 8 cm (3.2 inches) minimum height for both species, 3 mm (0.12 inch) minimum caliper for western larch and 4 mm (0.16 inch) for ponderosa pine. There were no maximum sizes. All seedlings, both shippable and cull, were

counted on each plot. The height and caliper of 10 randomly selected shippable seedlings were measured. From these figures, bed densities of total seedlings produced and seedlings meeting grade were calculated.

RESULTS AND DISCUSSION

Analyses of soil samples taken in the bedhouse and outdoors before planting and after harvest have not been completed, but it is unlikely that they will show major differences. Spring samples were taken only to check the assumption that soil conditions were uniform in all plots. The fall sampling will show the effect, if any, of treatments in this study.

Temperatures within the bedhouse were remarkably uniform, usually $\pm$ 1°C at all test points.

The objective of this experiment was to see if a bedhouse could reduce growing time for ponderosa pine and western hemlock from two seasons to one, and in these terms, the bedhouse was a success.

Table 1 shows the production of total and shippable seedlings of each species and seed source. Of the bedhouse-grown ponderosa pines, more than half met 1-0 grade standards, whereas virtually none of the outdoor grown did. Total seedlings produced in the bedhouse and outdoors were not significantly different.

Nearly half of the western larch in the bedhouse met 1-0 grade standards--three times more trees per unit area than from the outdoor beds. In addition, total number of western larch was about 50% higher in the bedhouse than outdoors. Performance in the bedhouse might have been even better, if bed densities had not been so high because of the unexpected increase in total seedlings produced.

Extrapolating these results to a fully utilized production facility, a 7 x 29 mm (22 x 96 feet) bedhouse with four beds 1.1 m (42 inches) wide could produce 21,000 ponderosa pine or 32,000 western larch as 1-0. If we figure a 5-year write-off for the structure, and that care for a full house would cost the same as for what was grown in the test, then 1-0 larch could be produced for $88 per thousand and pine for $134 per thousand. These costs are substantially higher than the $57 per thousand Coeur d'Alene charges for 2-0 stock, but they are not outrageous for an initial trial.

Figures 1 through 4 show the average growth in height and caliper of each seed source of ponderosa pine and western larch. Each data point is a mean of eight seedlings. The horizontal dotted line is the grading standard. Most seedlings were tall enough to meet grade standards, but failed to reach a large enough caliper.

Except for late summer height growth there was little difference in the performance of the Nezperce (Idaho) and Sitgraves (Arizona) ponderosa pine seed sources.

Height growth of bedhouse-grown ponderosa pine was slow in April, while those grown outdoors showed no such lag at the corresponding age. Bedhouse-grown western larch grew very slowly for three months, which the outdoor grown did not. A

Table 1.--Seed sown and seedlings produced in the bedhouse and the outdoor comparison bed

Species and seed source	BEDHOUSE			OUTDOORS		
	Seed sown	Total seedlings	Shippable seedlings	Seed sown	Total seedlings	Shippable seedlings
	number per m^2 (ft^2)					
Ponderosa pine						
- Nezperce	370 (34)	205 (19)	129 (12)	370 (34)	248 (23)	<1
- Sitgraves	430 (40)	355 (33)	194 (18)	430 (40)	334 (31)	<1
Western larch						
- Kootenai	860 (80)	506 (47)	258 (24)	860 (80)	377 (35)	97 (9)
- Lolo	750 (70)	571 (53)	248 (23)	750 (70)	334 (31)	75 (7)

Figure 1.--Average height of ponderosa pine of two origins in a bedhouse and an outdoor bed at Coeur d'Alene Nursery in 1977.

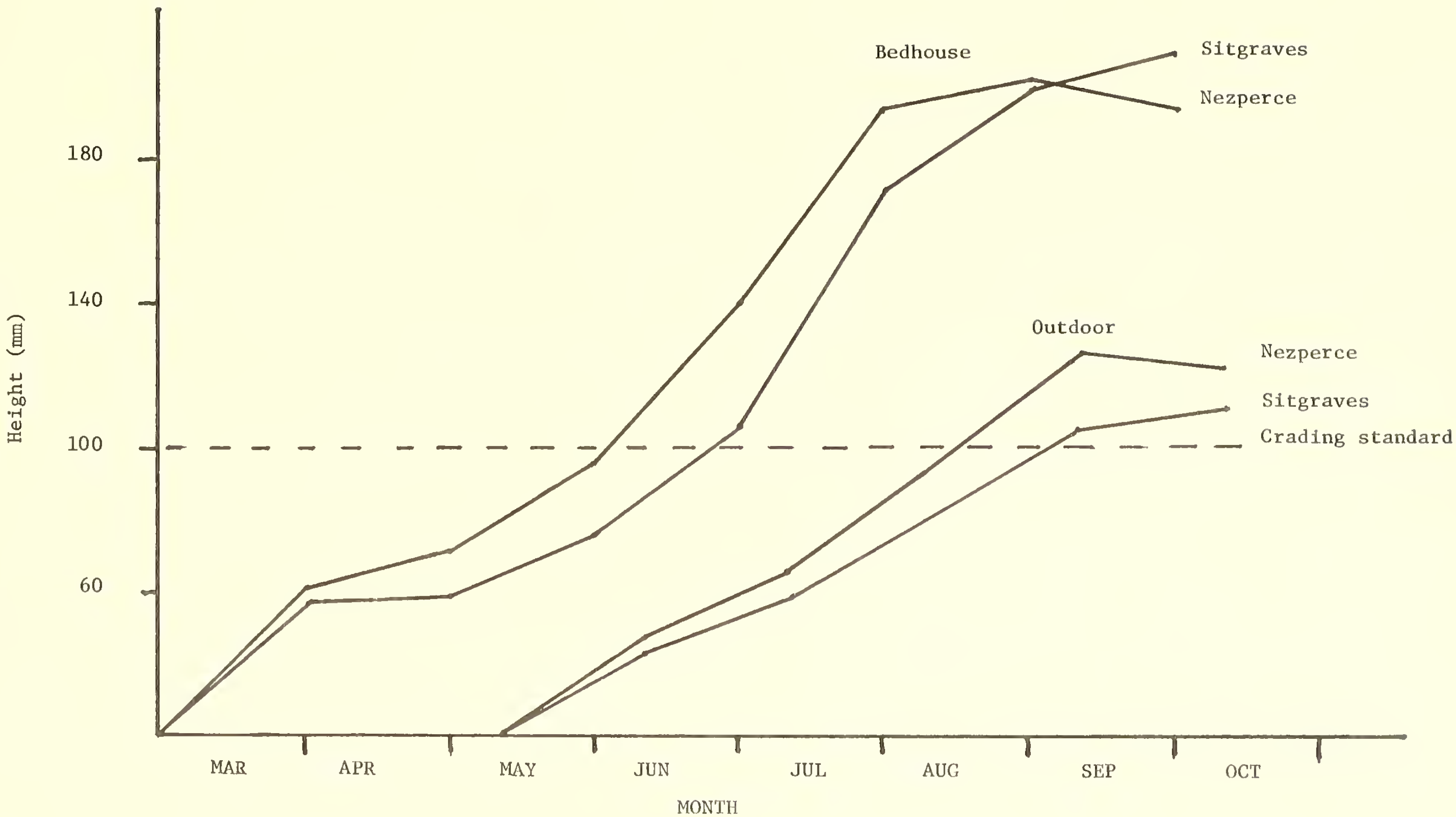


Figure 2.--Average caliper growth of ponderosa pine of a Sitgraves NF and a Nezperce NF origin in a bedhouse and an outdoor bed at Coeur d'Alene Nursery in 1977.

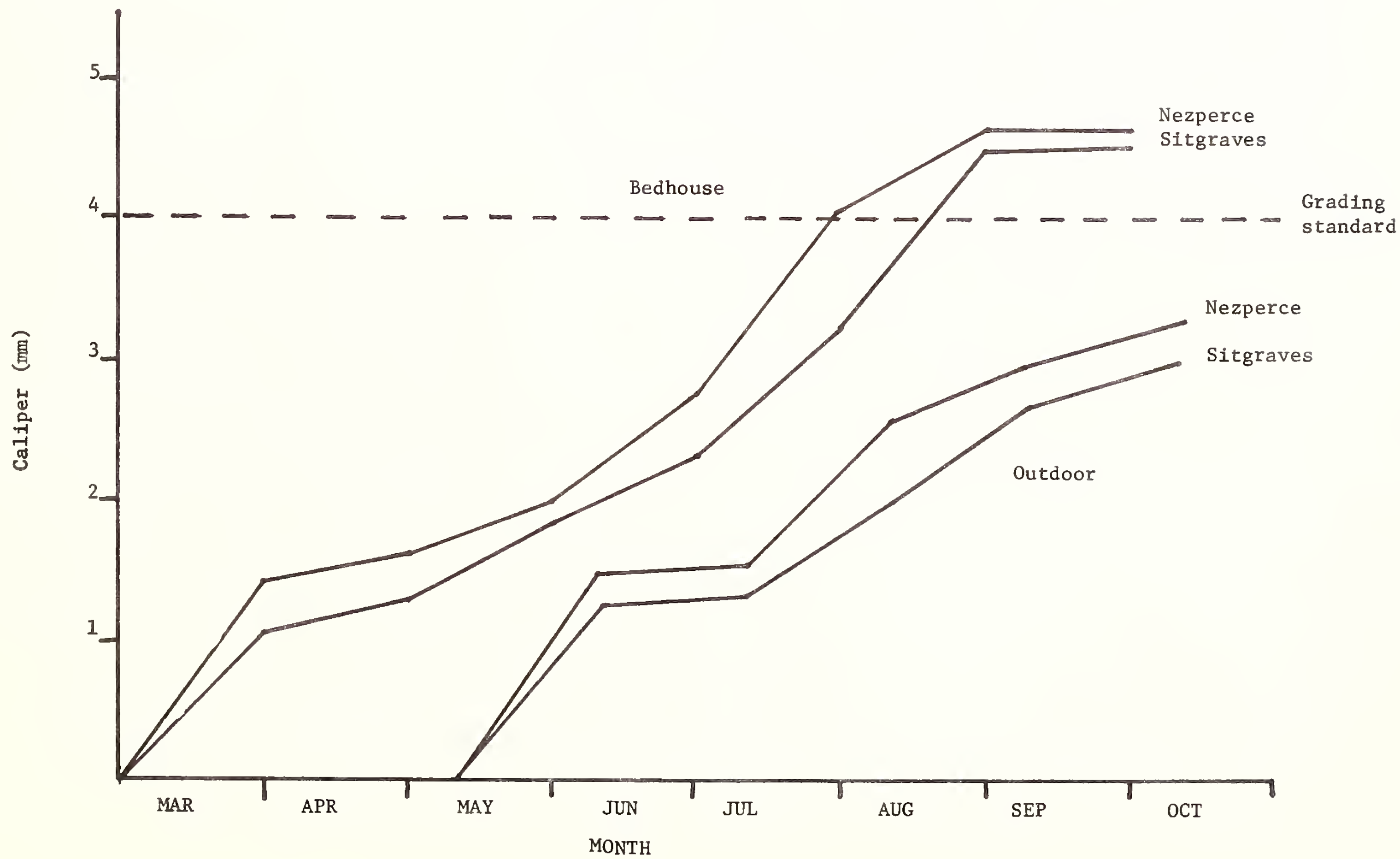


Figure 3.--Average height growth of western larch of two origins in a bedhouse and an outdoor bed at Coeur d'Alene Nursery in 1977.

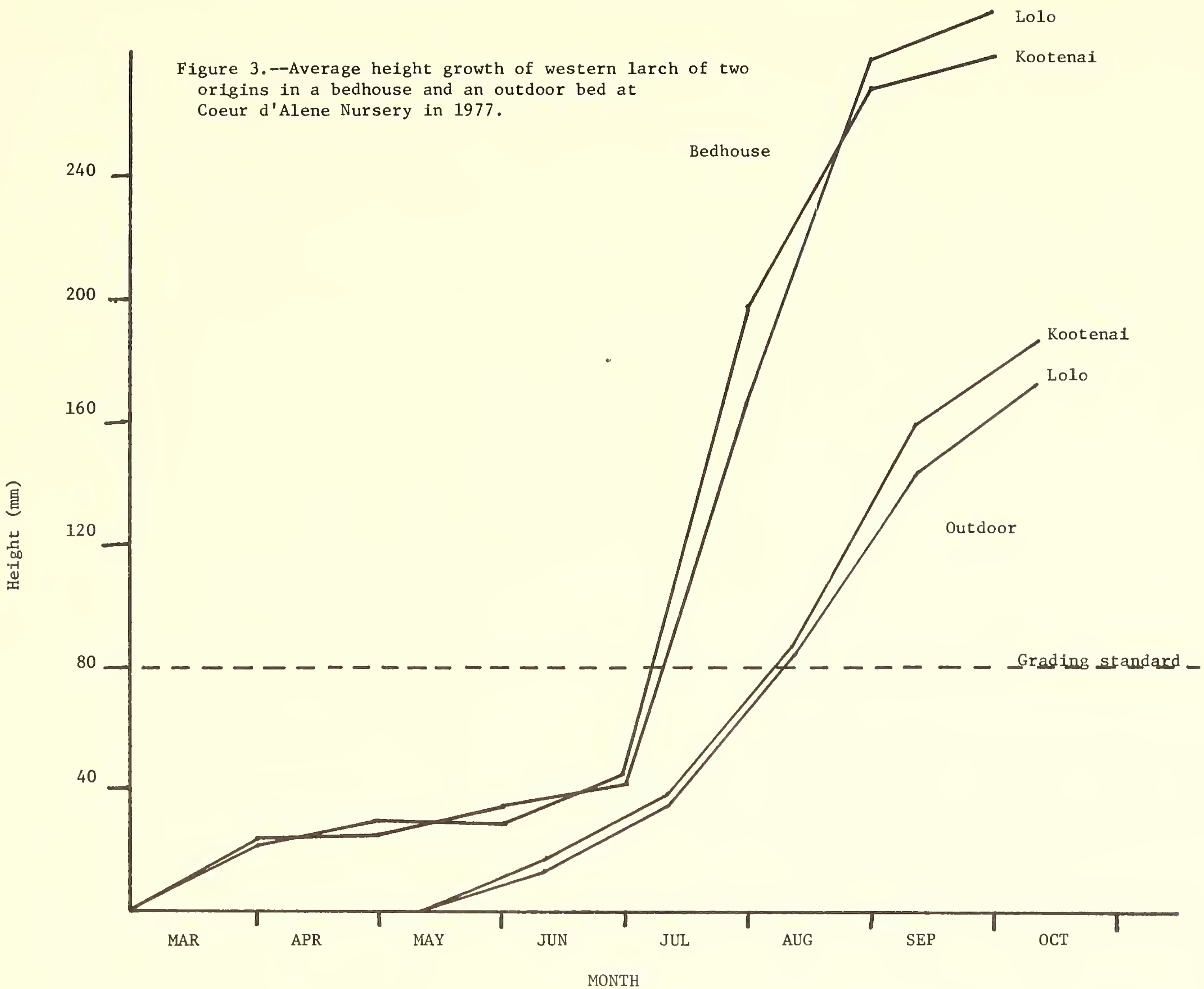
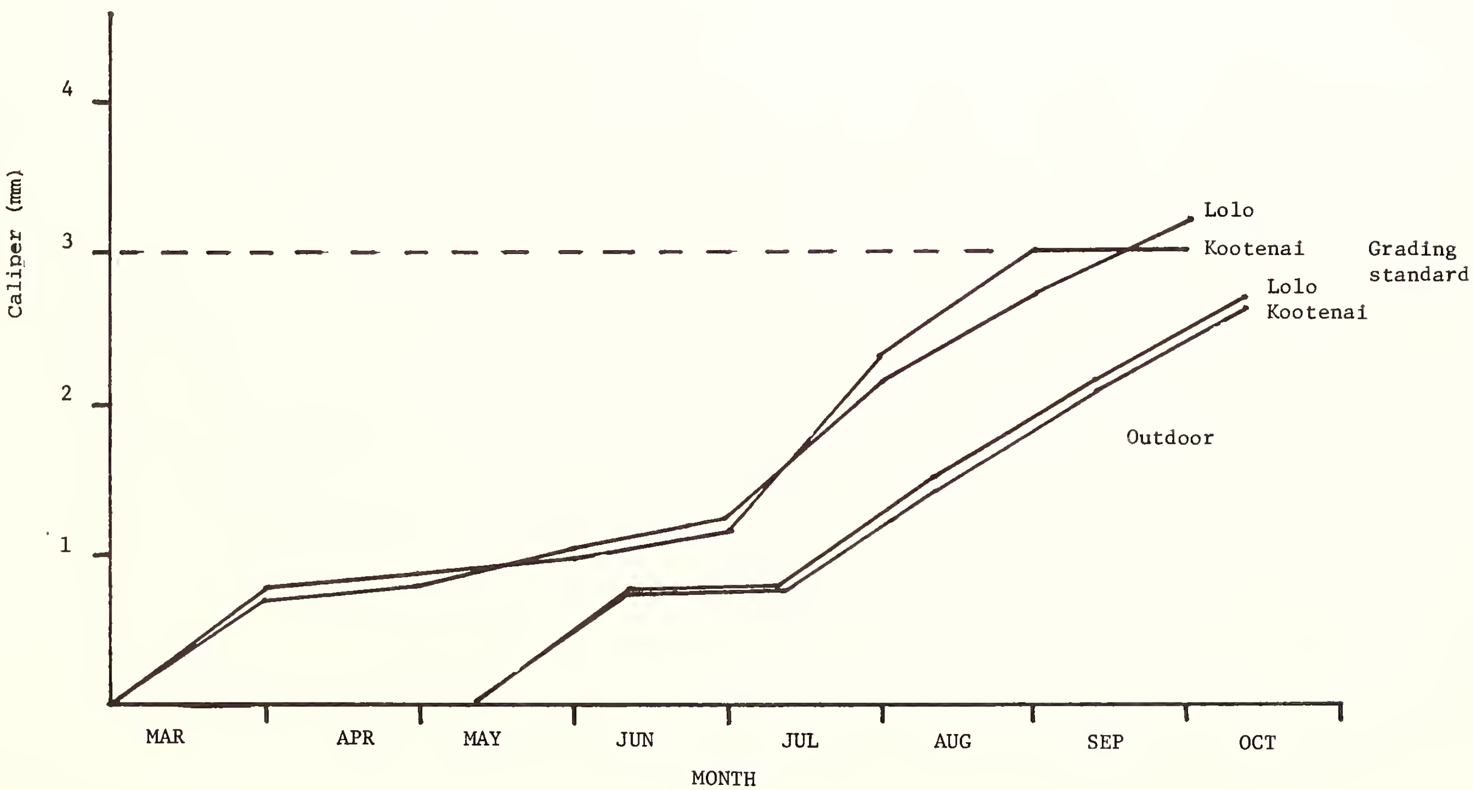


Figure 4.--Average caliper of western larch of two origins in a bedhouse and an outdoor bed at Coeur d'Alene Nursery in 1977.



similar pattern appeared in caliper growth except that there was also a one-month growth lag in the stock grown outdoors.

The most likely reason for the growth lag is that temperatures were suboptimum. Growth-chamber experiments and considerable greenhouse experience have shown that optimum day and night temperatures for ponderosa pine are between 20° and 25°C (68 and 77°F) (Tinus 1974). Nighttime surface temperatures were optimum only during the germination period (fig. 5). Day temperatures were also suboptimum for the rest of March and much of April and May, but were near optimum in June and July. August was too hot. Figure 6 shows mean day and night temperatures for that portion of the season between planting the outdoor crop and removal of the cover from the bedhouse. If figures 5 and 6 are superimposed, it can be seen that there was little difference in surface air temperatures between the bedhouse and outdoors except for the warmer night temperature in the bedhouse when it was still heated, and warmer day temperatures in May.

We do not have similar temperature effect information for western larch as we do for the ponderosa pine, but for Siberian larch optimum day temperatures are 24-28°C (75-82°F) and optimum night temperatures are 16-26°C (60-78°F) (Tinus and McDonald 1978). If we assume the two larches behave similarly (a hazardous assumption), then night temperatures were almost never warm enough except during the germination period. Except for a few warm days in April, optimum day temperatures were not reached until June. August day temperatures may have been more appropriate for larch than for pine.

The implication is that if warmer temperatures were maintained after germination, there would be no growth lag, and the same size seedling could be grown in a shorter time.

This year, Coeur d'Alene and Lucky Peak nurseries each have two bedhouses, and tests in progress will build on what we learned last year. One bedhouse each was seeded March 1, and temperature was maintained at 21° C (70°F) only during germination and then reduced to 10°C (50°F) just as it was last year. However, lights were added in this house to lengthen the photoperiod to the equivalent of a 24-hour day. The other bedhouse at each nursery was seeded April 1 and maintained at 21°C (70°F) minimum temperature until the heat was turned off at the end of May.

Coeur d'Alene is at 48°N, and all seed sources except the Sitgraves ponderosa pine are from similarly high latitudes. These seed sources can be expected to go dormant under the normal photoperiod prevailing in Coeur d'Alene in March and April, although germinants from seed sown March 2 may not be mature enough to set bud before long days arrive. Starting a month later (April 1) should make quite a difference in seedling response, but maintaining the minimum temperature at 21°C (70°F) for two months will be expensive even though the cold month of March is avoided. If an extended photoperiod can substitute for warm night temperature, it will undoubtedly be a cheaper cultural practice. We will not know until December what the results of our 1978 tests are.

What does the bedhouse offer nurserymen in the Southeast, where even 1-0 seedlings can grow too large? Bedhouses will certainly not replace the outdoor nursery, but there are special situations where they may prove useful.

Figure 5.--Mean day and night surface air temperatures in the bedhouse at Coeur d'Alene Nursery 1977.

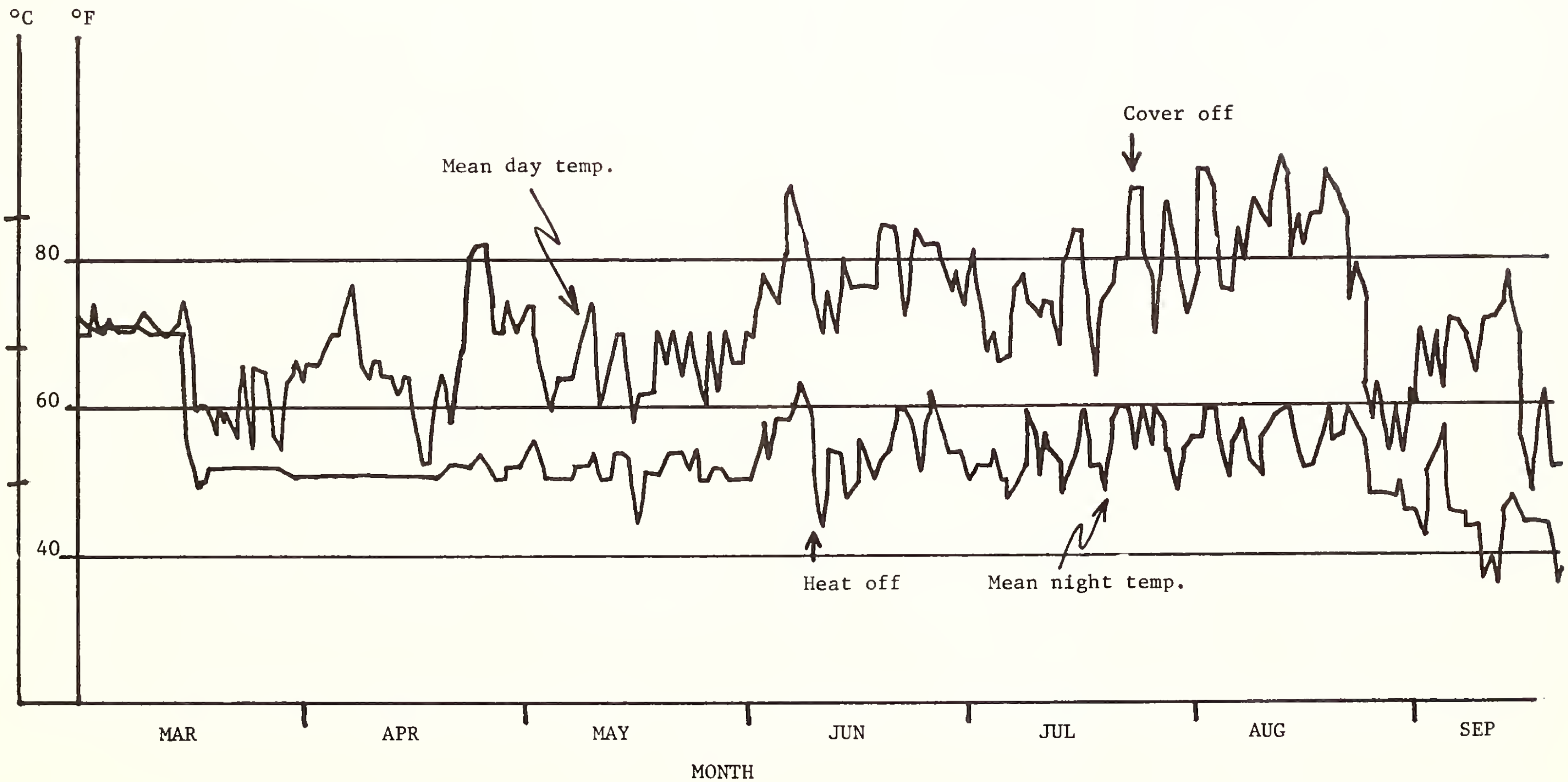
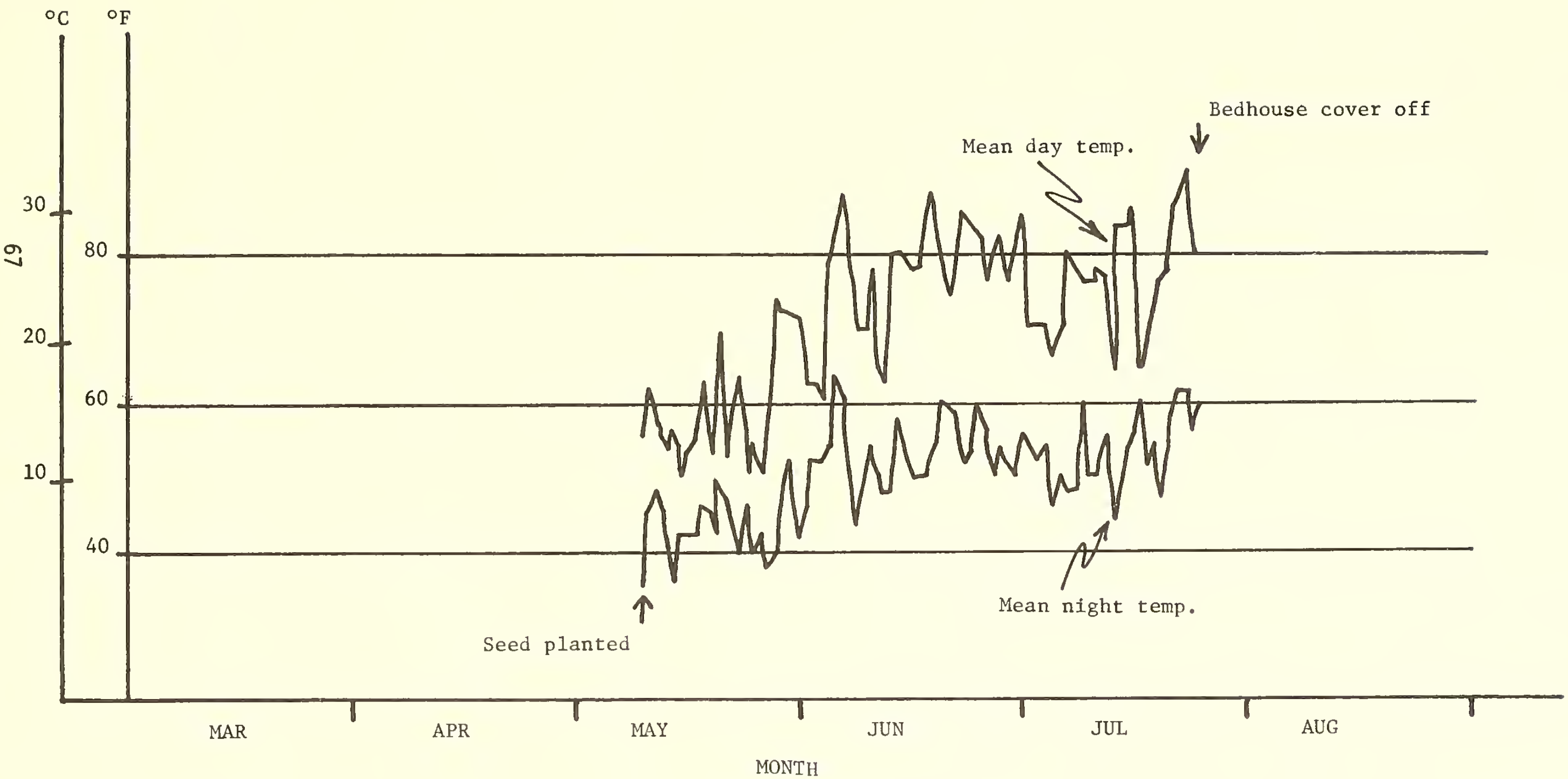


Figure 6.--Mean day and night surface air temperatures in the outdoor comparison beds.



North Carolina produces container-grown Fraser fir which is then transplanted outdoors and eventually sold as bare-root stock.[3/] Perhaps a bedhouse would permit rapid and direct production of the desired bare-root seedling at less cost.

Perhaps eastern white pine could be produced in one year in a bedhouse instead of the two years it takes outdoors. Perhaps shortleaf and Virginia pine could be raised to a larger size in a bedhouse, which ought to improve field survival.

I am sure each of you can think of other cases where a bedhouse might be useful. Here, I have tried to introduce you a new tool and show how controlled environment research is being used to assess the value of that tool and improve it for your use.

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USE OF THE GROWTH RETARDANT "MAINTAIN" BY GEORGIA KRAFT COMPANY

John J. Gill and Ray A. Newbold[1/]

Abstract.--The growth retardant MAINTAIN(TM) at the concentration of 300 PPM was beneficial in preparing loblolly pine for extended season planting. When applied soon after bud break, the terminals died, new buds formed and remained quiescent until August, stems and roots continued to develop. The planting season was extended by "storing" seedlings in the nursery bed and lifting them fresh as needed.

Additional keywords: Growth retardant, extended season planting, *Pinus taeda*.

A problem which has plagued Georgia Kraft Company is too many timberland acres to regenerate in too short of a time. In 1967 consideration was given to extending the four-month planting season, December 1 to March 31, which is acceptable if holidays and weather are not considered. During this season, pine seedlings are normally dormant which is the optimum condition for outplanting.

In addition to the large acreage to regenerate, there were idle men and machines in the off-season. Tree planters and tractors are expensive, making it difficult to justify the need for machines that are used a third of the year. Also, labor is an important factor with increasing wages and Company benefits. By extending the planting season, it was considered possible to plant more acres with fewer men and machines.

At this same time, there was research being conducted in Florida to plant slash pine (*Pinus elliottii* Engelm. var. *elliottii*) during the summer rainy season. The idea to use MAINTAIN (MAINTAIN-CF125 - U.S. Borax Co.) originated with Dr. Walter Beers of Buckeye Cellulose.

MAINTAIN-CF125 is manufactured by U.S. Borax and is available as an emulsifiable concentrate containing 12.5% a.i. This active ingredient interferes with the development of early growth stages in both monocotyledonous and dicotyledonous plants. MAINTAIN acts systemically being translocated from the leaves (or needles) to the meristematic tissue.

In the first tests, MAINTAIN was selected as the growth retardant and it was compared to sheared and cold storage loblolly pine (*Pinus taeda* L.) seedlings. In 1975 this research was expanded to other growth retardants. This report is a summary of this research and it is not an endorsement of a specific product.

PROCEDURE

During the evaluation of the use of MAINTAIN, several tests were carried out which overlapped in time which will be described separately in this report.

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The first study was initiated in the early winter of 1971 with the assistance of Dr. Mervin Reines, University of Georgia. A portion of a nursery bed at Georgia Forestry Commission's Morgan Nursery was reserved for the study involving 12,000 seedlings. These seedlings received the following treatments:

1. Portions of the bed were sheared at various times throughout the growing season to keep seedlings 8-10 inches and 12-14 inches in height.

2. Approximately 2,000 seedlings were sprayed with MAINTAIN, 300 PPM aqueous solution to which was added a spreader sticker (Reines, 1972). This application was made shortly after the beginning of terminal elongation.

3. Two bags of seedlings were lifted and placed in cold storage in the company's seed stratification room (35^{o}-48^{o}F) on the last day of operational seedling lifting. Roots were kept moist during storage (Newland, 1972).

Beginning on April 22 and continuing bi-weekly until November 19, 1971, seedlings were removed from the nursery beds and cold storage and hand planted using a replicated, randomized, split plot design. Two more chemicals were added to the test - "WILTPRUF," a top dip antitranspirant and a root dip of an alginate to prevent drying, tradename "AGRICOL" (Kennesaw Chemical Company). Survival by planting dates for the first 14 plantings is shown on Table 1.

Seedlings were lifted by hand or removed from cold storage on the day of planting. Upon counting, the sheared and cold storage seedlings were treated with AGRICOL or WILTPRUF and placed in buckets. The MAINTAIN-treated seedlings did not receive the root or top dip. The AGRICOL-treated seedlings received no further protection. All other treatments had the roots packed in wet peat moss. Seedlings were then transported to the planting site in Greene County, Georgia. Special precautions were taken at all times from lifting to planting to reduce root exposure.

Results of the above treatments were quite satisfactory as the summer of 1971 experienced well-distributed rainfall. Only three planting dates were classified as dry (May 7, June 4 and October 6), causing difficulty in hand planting. The treatments were analyzed and MAINTAIN was found to be a dependable treatment for extended season planting.

Many implications can be made from the data, but the big result was that fresh, quiescent seedlings were suitable for summer planting. While giving good results, shearing required four applications to maintain the desired seedling height.

When applied at bud break, MAINTAIN prevented terminal growth until early August; thereafter, growth was rapid until fall. This rapid late growth did not occur in the other treatments. MAINTAIN-treated seedlings respond with the death of the terminal bud or fresh shoot - the old needles were retained and diameter growth continued. The diameter growth produced stout, somewhat stiff seedlings which have been found difficult to plant (Newland, September, 1973).

Table 1.--Percent survival by planting date and treatments - October, 1971

Treatment	PLANTING DATE														
	4/27	5/7	5/21	6/4	6/18	7/2	7/14	7/29	8/12	8/26	9/8	9/22	10/6	10/20	Avg.
Sheared to 8"	87	90	93	43	93	93	93	83	80	80	83	63	43	100	80
Sheared to 8" + WILTPRUF	87	87	87	40	87	66	43	0	1	53	17	13	40	97	51
Sheared to 8" + AGRICOL	100	97	90	63	97	97	90	67	60	83	77	67	50	97	81
Sheared to 12"	80	80	87	60	93	80	80	77	57	77	83	63	53	100	76
Sheared to 12" + WILTPRUF	80	83	37	43	90	60	30	13	0	37	47	53	60	100	52
Sheared to 12" + AGRICOL	87	87	97	57	90	77	80	70	43	70	63	67	40	100	73
MAINTAIN	83	83	93	63	97	90	90	90	53	90	77	67	60	90	80
Cold Storage	67	77	63	30	87	83	70	93	73	NA	NA	NA	NA	NA	71 1/
Cold Storage + WILTPRUF	87	67	63	50	90	77	83	63	50	NA	NA	NA	NA	NA	72 1/
Cold Storage + AGRICOL	NA	NA	NA	NA	73	77	63	80	NA	NA	NA	NA	NA	NA	73 2/
Cold Storage + AGRICOL + WILTPRUF	NA	NA	NA	NA	83	83	67	57	NA	NA	NA	NA	NA	NA	72 2/

1/ Average applies to first nine periods only.

2/ Average applies to periods 5, 6, 7, and 8 only.

J.E.N.
2/29/72

Table 2.--Percent survival on February 1, 1973, percent soil moisture on day of planting and rainfall for the following two-week period

Planting Date	Treatment[1/] 1	2	3	4	5	6	7	8	9	Soil Moisture % of Wet Wt.	Rainfall Between Dates
5/3/72	72	86	69	51	70	56	55	81	68		
5/17/72	75	81	77	71	76	79	74	86	86	13.3	1.67
5/31/72	75	84	61	43	45	36	67	58	31	13.4	0.43
6/14/72	67	81	78	51	62	38	44	70	41	8.0	6.38
6/28/72	77	76	78	48	77	52	52	81	55	12.2	3.10
7/12/72	40	34	30	14	13	09	12	40	06	22.4	0.70
7/26/72	80	71	64	45	69	17	39	58	46	9.9	3.16
8/9/72	15	35	15	06	16	00	08	37	06	5.5	1.79
8/23/72	00	04	01	00	00	00	00	01	00	3.4	1.59
9/6/72	01	00	00	00	01	00	00	00	00	5.6	0.40
9/20/72	00	00	00	00	00	00	00	00	00	3.3	0.75
10/4/72	02	06	00	23	15	27	09	34	05	6.0	0.15
10/18/72	00	01	06	24	38	21	27	42	27	5.6	0.00
11/1/72	00	00	00	96	92	82	94	90	96	8.3	2.11
Overall	36	40	34	25	41	30	34	53	33		

1/ Treatment description

No.	Description
1	Cold stored
2	Cold stored and water
3	Cold stored and AGRICOL
4	Sheared
5	Sheared and water
6	Sheared and AGRICOL
7	MAINTAIN
8	MAINTAIN and water
9	MAINTAIN and AGRICOL

After the 1972 growing season, the tests were checked for survival, height growth and forking habit (Newland, April, 1973) which indicated no statistical difference for seedlings treated by shearing or MAINTAIN. Seedlings treated by either shearing method or MAINTAIN survived better and forked at approximately the same rate as cold storage seedlings.

After the 1973 growing season, the 1971 plantings were remeasured to compare the effect of MAINTAIN on height growth with cold storage seedlings (Newbold, May 7, 1974). The data were paired by planting dates and it was concluded that there was no significant statistical difference in height growth which led to the conclusion that there was no residual effect on terminal growth after the first season.

In 1972 a second study was installed to determine if the results from 1971 study were biased by the favorable rainfall pattern in 1971. In this test three main treatments were tested - cold storage, shearing to 8" and treating with MAINTAIN. On these three treatments were imposed two additional treatments - watering in with 0.1 gallon of water in the planting slit and dipping the roots in AGRICOL. The planting dates and survival are presented in Table 2 (Newland, May, 1973).

There were several differences in the two plantings. First, the rainfall in 1971 was slightly above normal and exceptionally well-distributed. In 1972 the rainfall was also slightly above normal, but was unevenly distributed. The normal dry period from late July through October produced almost drought conditions. The 1971 plantings were on a Davidson clay loam and the 1972 plantings were on a Molena sandy loam. The result was poorer overall survival in 1972.

In an attempt to secure better survival, the cold storage seedlings were kept in sealed plastic-lined bags until planting and these seedlings survived better than either the MAINTAIN-treated or sheared seedlings until late July when all treatments failed. In October, survival picked up for the sheared and MAINTAIN-treated seedlings which indicated that cold storage seedlings have a limited life in the bag. After the last of July, the bagged seedlings were not considered usable.

Watering improved the survival of the three basic treatments. Though not operationally feasible, this reinforced the belief that adequate soil moisture was necessary (Newbold, May 1, 1974) which makes upland sites of coarse soils not suitable for summer plantings.

<u>Developmental field tests</u>

Based on the 1971 test, operational tests were initiated on the Georgia Kraft Company Developmental Forest, Greene County, Georgia (Carson and Presnell 1975). Over a period of three years, 600 acres were planted with MAINTAIN-treated loblolly pine seedlings. The area planted was eroded Piedmont land which had been clearcut and site prepared by two chops with rolling drum cutters. The planter was a Reynolds double coulter pulled by a light crawler tractor equipped with a V-blade.

After the start of shoot elongation, MAINTAIN treatment was applied at the standard rate of 300 PPM (active ingredient) in 1972 and 1973. In 1975 the treatment was applied prematurely on dormant buds in February and had to be repeated in early April. The treatment kept the seedlings in a quiescent state until mid-July or early August. The new shoots typically twisted, curled, dried up, and fell off; however, new buds formed and remained dormant. Despite the first flush being lost, the seedlings in the beds continued to grow in diameter and developed a fibrous root mass requiring the trimming of some roots prior to planting.

For the three years reported, procedures varied to consider improvement in techniques as the result of previous observations. Permanent plots were established to monitor survival and growth - five rows of ten well-planted trees each.

1972

On three different dates, trees were lifted by regular nursery techniques starting at 8:00 a.m., placed in tubs, carried to the building for packing, and transported to a 58°F cool cellar. One day's planting was taken from storage at a time, and planting was conducted three days per week from May 15 to August 18, starting at 8:00 a.m. During this period, 150 M seedlings were planted on 275 acres and survival ranged from 93% to 10%.

1973

Lifting of seedlings in the nursery was changed to first light and all packing completed by 10:00 a.m. and the seedlings were placed in cool storage by noon. Seedlings were planted two days per week for six weeks, from June 6 to August 8. The scheduled workday was from 5:30 a.m. to 1:00 p.m. Fifty thousand seedlings were planted on 72 acres with survival between 89% and 48%.

1975

Seedling lifting began at first light, bagged in the field, and the sealed bags were placed in a refrigerated van at 35°-40°F within one-half hour after lifting. Planting was carried on for a full five-day week as weather and soil permitted, starting at 5:30 a.m. Survival was between 91% and 24% over the 293 acres planted.

The review of this work concluded that changes in practices at the nursery helped maintain the viability of the seedlings. Refrigerated vans are now a routine method of transporting seedlings. Storage at 35°-40°F retains seedling vigor better than at 58°F. Survival showed a definite decrease as storage time increased. An attempt was made to schedule planting sites by soil moisture conditions which proved impractical in the highly variable terrain due to loss of control and the crew spending a lot of time moving. The schedule evolved to one of plant the entire tract or do some other activity that day.

As the result of scheduled operational planting, several observations can be made: (1) If lifted weekly, MAINTAIN-treated seedlings will usually do well in May and June and during July and August they may be used on sites with favorable soil and moisture conditions; (2) soil and site seem to exert stronger influence than rainfall on survival; (3) during dry seasons the seedlings continue growing in the nursery beds and are available for the next season's planting; and (4) advance planning is a must for successful extended season planting.

Operational results

Operational planting and planning differ slightly from research or developmental work. During 1972 a wet, mixed-up season resulted in the tree planters being behind schedule. After bud break in the nursery, there remained a large number of seedlings to be planted. MAINTAIN was applied to 500 M seedlings which looked like a disaster when the withering flush was ready to drop. In 1974 conditions again required the operational use of MAINTAIN. Three areas were planted with a D-8 tractor pulling a pair of Taylor heavy-tapered disc tree planters. The following observations were made by operating personnel in each area:

1. Kathleen, Georgia (1972) - April and May, dry weather and medium texture soil, 76 acres, 50% survival, at three years trees looked good.

2. Kathleen, Georgia (1972) - April and May, dry weather, black gumbo soil, 192 acres, failure.

3. Monticello, Georgia (1974) - April, sandy clay loam, full stand survived. Many of the seedlings lost all their needles before a flush emerged in August.

4. Griswoldville, Georgia (1974) - April, sandy to sandy loam (Fall Line hills), 5 acres, survival 70%, planted with Reynolds double coulter and D-4.

SUMMARY

Georgia Kraft Company continues to have a need for an extended planting season. Research has provided several tools which, if used properly, permit successful planting for at least six months; however, pine seedlings are living organisms which have certain requirements that must be met for survival.

Three treatments have proven successful:

1. Shearing - This treatment requires more attention than other methods as survival is effected by the physiological state of the plant at the time of lifting. This method is best used for keeping seedlings in the nursery briefly after the normal planting season which requires planning of nursery space. Also, the treatment is very labor intensive.

2. Cold storage - More nurseries and planting crews are utilizing cold storage to insure the viability of the seedlings after lifting. If lifted before bud elongation, these seedlings have a shelf life of up to three months. The plastic-lined bags, which do not require watering until the seal is broken, store better than "jelly roll" bales. Temperatures of approximately 35°F have been most effective for storage. Cold storage also eliminates some of the problems in the coordinating of nursery and planting operations.

3. MAINTAIN treatment - The beds to be treated need to be remote from normal nursery operations. MAINTAIN should be applied after the buds break. Early application requires a repeat job and late application takes more out of the plant than necessary. Once MAINTAIN is successfully applied, no additional treatment is required until the seedlings are lifted.

With each of these treatments, the longer time extension beyond the normal planting season the more care is required to retain seedling viability. Supervision is the key to success of late season planting in that no treatment will be successful if the material is allowed to go into heat, exposed roots allowed to dry out, or sites are planted after the soil is too dry.

In 1975 a new study was installed at Alabama's Stauffer Nursery to evaluate other growth retardants (Little, 1977). In this study MAINTAIN was the control and four other commercial growth retardants were tested at the manufacturers' prescribed rates. Several retardants gave indications of potential value and one appeared to be the equal of MAINTAIN. Future studies will be implemented as a result of these preliminary evaluations.

The following characteristics were noted when loblolly pine seedlings were treated with MAINTAIN:

1. Seedlings treated before bud break will have to be retreated.

2. Seedlings treated after the bud elongates will have the terminal buds brown and die. The plant will develop new buds but will remain quiescent until about August.

3. With height growth retarded, the seedlings continue to grow in diameter and develop a fibrous root system. Thickening is noticeable on the stem with a layer of wood resembling summer wood being built up. In a short time, these seedlings are growing thicker, stiffer stems which tend to be more brittle than normal as a result of their continuing to store energy. Some treated seedlings tend to grow pear-shaped (similar to one with a basal Cronartium infection).

4. Two to three years after planting, the MAINTAIN treatment is no longer noticeable with normal height growth and average forking. When outplanted during a dry spell, some have lost all their needles, and now these seedlings can only be identified by the planting site.

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The Missoula Equipment Development

Center Reforestation Program

Richard Hallman and Allan Cluster 1/

Introduction

The Missoula Equipment Development Center is one of two Development Centers in the Forest Service. The mission of Forest Service Equipment Development is the systematic application of scientific knowledge to create new or substantially improved equipment, systems, materials, processes, techniques and procedures that will perform a useful function and be suitable to meet the objectives of advanced forest management and utilization.

The Missoula Center was established in the early 1950's to develop and test equipment for forest fire control. In recent years the emphasis has shifted to resource management and especially to timber management. This morning I'd like to briefly talk about a few of our reforestation projects and a few of the projects in our Cooperative Forestry Program.

The reforestation program is primarily aimed at solving equipment problems in the National Forest system. The cooperative forestry program is aimed at helping state and private forestry organizations with their equipment problems.

TECHNICAL SERVICES, TIMBER MANAGEMENT

In both programs, we have a technical services project to help field personnel with routine equipment problems. This project also helps us keep current with real field needs. We periodically use surveys to determine these needs and help us put priorities on equipment needs as well as formulate development schedules. A recent survey of timber management personnel on all National Forests showed that harvesting cones and seeds is their most pressing problem.

TECHNICAL SERVICES, NURSERIES

Our cooperative forestry technical services nursery projects gives engineering help to state and private nurseries. In 1973 we surveyed all federal, state and private forest tree nurseries to determine their needs. The results helped direct our work. The main thrust of this project for the next few years will be to make engineering drawings of custom built nursery equipment to enable nurseries to reproduce this equipment.

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PRECISION NURSERY SEEDER

Nursery bed sowing is a high priority problem.

What may look like good spacing and density control from a distance, is not under close scrutiny. We began this project by evaluating numerous existing seeders in the lab and in the field.

We also looked at new concepts such as the 8 row tape seeder. We had a prototype gravity seeder built under contract. Our tests indicated and the nurserymen agreed that the Norwegian-built Øyjord seeder would best meet the industries' immediate needs. In addition to placing the seed as desired, the machine is designed to use with small seed lots and is easy to clean and calibrate. The Center has worked with a Washington State manufacturer to make the seeder available in this country.

INTENSIVE NURSERY CULTURE

Nurserymen are always looking for ways to improve their product and at the same time keep their costs down. In the last 10 years, the concept of growing containerized seedlings in greenhouses has become popular in some parts of the country because close environmental control can be achieved. However, the practice can be very expensive. Costs of over $100 per thousand are reported. Bareroot stock is usually much less expensive, but the crop is vulnerable to adverse weather and to insect and disease attack.

Center engineers are working with researchers like Dr. Tinus of the Shelterbelt Laboratory in Bottineau, N.D., to evaluate a system that incorporates some of the advantages of the greenhouse without all of its costs. Dr. Tinus, with the help of Coeur d'Alene Nursery personnel is evaluating the growth potential and the economics of the so called "bedhouse" concepts. The idea is to start the crop 6 to 8 weeks early under cover and then remove the cover when protection is no longer needed. Only time will tell if this method of growing seedlings will catch on in this country as it has in northern Europe.

EQUIPMENT FOR PROCESSING SMALL SEED LOTS

With the tree improvement program gaining momentum across the country, foresters are looking for equipment better suited for treating small seed lots. A catalog was assembled to show available small seed lot processing equipment. In the process of assembling the information, we found that there was a need for a small seed lot dewinger. The Missoula dewinger features soft rubber flaps that significantly reduce mechanical seed damage. The machine is available from several commercial shops or can be built from drawings available from MEDC.

MONITORING GREENHOUSE ENVIRONMENTS

Growing trees in greenhouses gives the nurseryman a real opportunity to control growth of his crop. However, he must know what environment affects his plants. Center engineers have worked with Oregon State University to design and build a greenhouse monitoring system. Sensors that measure conditions such as temperature, soil moisture, and PH have been mated with a small computer to measure

the various parameters on tape at any desired frequency. The computer can be used to analyze the data to regulate the greenhouse environment. This project will be completed this year with reports available at the Center to describe the system.

CONE AND SEED HARVESTING

As mentioned earlier, the problem of harvesting cones and seeds is perhaps the most critical problem in reforestation today. While the south is far ahead of other sections of the country with its thousands of acres of tree seed orchards, the problem of economically harvesting the persistant loblolly pine cone remains. One approach that is being tried is the vacuum pickup. Private timber companies in the south have financed the development of the Bowie Vacuum Harvester which is designed to vacuum loblolly seed from the orchard floor. Center engineers have participated in the machines evaluation.

The vacuum head sweeps over the orchard floor and picks up the seed as well as most other small material. The seed and other fine material is deposited in the revolving drum located on the side. Pine straw and other large material is walked out the back.

The performance of the machine depends on many factors such as weather, amount of debris on the orchard floor, and operating speed. It appears that this machine may become a useful tool, but only when operating conditions are just right. The Georgia Forestry Commission has been experimenting with plastic netting for collecting loblolly seed at their Arrowhead Orchard. Netting is pulled from a trailer to totally cover the orchard floor. The edges are stapled together to form a solid cover. The netting is kept in place to catch seed shaken from the tree or seed that falls naturally. It can be left in place throughout the seed fall period, then rolled up. The seed and debris are left in a windrow in a road to be processed with a combine.

The Center is working with the Georgia Forestry Commission to design and build a new trailer to deploy and retract the netting as well as separate the seed from the debris through a built-in combine. We plan to have the new equipment ready for testing at Arrowhead this fall. This fall the Center will also begin developing improved equipment for cone collection in the western United States where terrain often limits mechanization. We are preparing a slide-tape series that will help field personnel make the most of available techniques. The three part series will include cone development, which will elaborate on the life-cycle of a cone, inventory techniques, and will describe common collection methods and how they should be employed.

INSTRUMENTATION TO MEASURE SEEDLING DORMANCY

Nurserymen have needed a simple reliable method of determining when their seedlings are dormant.

Plant physiologists have recently found that when electrical impedence through seedling tissue is displayed on a square wave oscilloscope, changes in the trace can be used to estimate the degree of dormancy. Besides being useful

for research, the technique can be used by nurserymen to regulate lifting schedules.

Unfortunately the equipment being used is expensive and bulky. Center engineers are attempting to replace the oscilloscope with a small solid state instrument that would be much easier to use. Ten of these prototype dormancy meters are being evaluated by plant physiologists in this country and Canada.

INVESTIGATION OF SEEDLING HANDLING PROBLEMS

This year we began examining the problems of handling seedlings from the time they are lifted until they are planted. We are concentrating on the problems of the packing shed where culling, grading, sorting, and packing is usually done. Because this is typically a labor-intensive operation, about one-third of the cost of producing a seedling is accounted for here.

A select group of nurserymen and researchers are working with us to find ways of streamlining the operation. The first concept that will be evaluated is a stacked 3-belt seedling grading system that will be tested in California later this year. Other design concepts will be evaluated later.

PLANTING AUGER

Throughout the country there are areas where only hand planting can be done because of terrain. Conventional planting tools are often ineffective because they cannot make a sufficiently deep hole for long-rooted seedlings. To solve the problem, planting augers are being used to plant large bareroot stock. The system has its drawbacks, however, because many of the augers weigh over 50 pounds, and are bulky and hard to handle.

The Center is evaluating some newer lighter machines that generally weigh less than 30 pounds. Lightweight chainsaw engines are hooked to gear boxes with speeds that vary from 200 to 400 RPM. Different speeds are needed in various soil types for each auger. As part of this project we are evaluating new auger designs and new ways to harden augers to make them last longer.

REFORESTATION AND TSI EQUIPMENT HANDBOOK

The last project I would like to touch on today is a reforestation and equipment handbook we are currently putting together. The handbook will be similar to the Nursery Equipment Catalog we recently distributed. It will list equipment available for use in all phases of reforestation and timber stand improvement. It will briefly describe various types of equipment, how to use it, and where the equipment is available. This handbook will be available next summer.

RESISTANCE TO PULSED CURRENT MAY INDICATE DORMANCY IN TREE SEEDLINGS

W. J. Rietveld and Robert D. Williams1/

Abstract.--Nine deciduous and four coniferous species at two nurseries were monitored for variation in electricl resistance during fall 1977. Increasing resistance appeared to coincide with the onset of dormancy in most of the deciduous species. Less indicative patterns of resistance were noted in most of the conifers. A change in electrical resistance was first noted at the terminal bud and then at the root collar.

Additional key words: Shigometer, time of lifting, *Juglans nigra.*

Hardwood nurserymen often lift seedlings in the fall because it allows them to: (1) schedule work for a longer period, (2) have seedlings ready for early spring planting regardless of local weather conditions, and (3) know how many shipable seedlings are on hand.

For best overwinter storage and transplanting success it is important to wait until seedlings are dormant before they are lifted. Seedlings lifted too early may mold or die in storage or have reduced root regeneration after transplanting. Various dormancy indicators are used by nurserymen--a killing frost, etc.--but none of them are totally reliable.

An instrument to detect seedling dormancy would eliminate depending on less certain indicators to determine when lifting may begin. Therefore, we have been testing a portable DC ohmmeter (Shigometer®, model 7950, Northeast Electronics Corp., Concord, NH)2/ to see if a change in resistance to pulsed electric current can be used to detect onset of dormancy in seedlings of 13 species--9 hardwoods and 4 conifers--at two nurseries (fig. 1). The meter detects changes in resistance as concentrations of cations in plant tissue vary (Skutt *et al*. 1972). We have already reported a strong inverse relation between resistance to pulsed electric current and root regeneration potential of black walnut seedlings (Rietveld and Williams 1978).

MATERIALS AND METHODS

Seedlings at the Jonesboro nursery in southern Illinois and the Vallonia nursery in southern Indiana were monitored in the seedbeds biweekly from

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1/ Research Plant Physiologist and Principal Silviculturest, North Central Forest Experment Station, USDA Forest Service, Carbondale, Illinois and Bedford, Indiana, respectively. We wish to thank Mr. Jim Wichman and Mr. Mel Gerardo, nurserymen at Vallonia and Jonesboro, respectively, for their excellent cooperation and Alex L. Shigo, David S. Fensom, Donald H. DeHayes, and Chip Williams for their technical reviews of the manuscript.

2/ Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.

Figure 1.--The Shigometer measures resistance to an introduced pulsed electric current. The meter indicates relative changes in concentration of mobile ions; as ion concentrations increase, resistance to pulsed current decreases and *vice versa*. The electrode handle is fitted with 5 mm long uninsulated stainless steel electrodes set 1.2 cm apart.

October 3 to late December 1977. Species included in the study were:

Jonesboro	Vallonia
Black walnut	Black walnut
Red oak	Red oak
Yellow-poplar	Yellow-poplar
Green ash	Green ash
Autumn olive	Autumn olive
White oak	Sycamore
Sweetgum	European black alder
Eastern white pine	White pine
Loblolly pine	Red pine
	Scotch pine

At each testing date, 15 median-diameter seedlings were sampled at random in the nursery beds; different seedlings were sampled each time. Seedlings were monitored by inserting a two-needle probe into the cork cambium-phloem-vascular cambium-outer xylem region of the stem 3 cm above the ground line and 3 cm below the terminal bud. Uninsulated, stainless steel needle electrodes 5 mm long set 12 mm apart in a cast plastic probe handle (Delmhorst Instrument Co., Boontown, New Jersey) were implanted in a vertical line into the stem. The electrodes were fully embedded in all species except the pines, alder, and olive where they protruded through.

The Shigometer introduces a 0.5 ms pulse of 0.5μA every 10 ms and measures resistance to this current (Skutt et al. 1972). Measurements can be read accurately to the nearest 0.5 K ohm.

Regression curves were fitted to the data using the equation $Y = ab^x$, where Y is resistance and x is days from October 3.

Because temperature significantly influences seedling electrical resistance (ER) (Fensom 1966), it was necessary to adjust resistances to a common base temperature. We determined the relation between temperature and ER and developed a temperature correction as follows:

1. Working inside a controlled-environment room, 6 groups of 10 black walnut seedlings were repeatedly probed at intervals of 10 to 15° F within the range 10 to 90°F. Three groups were tested in separate warming cycles and 3 groups were tested in separate cooling cycles; 2 hours were allowed for seedling temperature to stabilize at each step.

2. The data were best-fitted with two linear regressions; one for temperatures below 32° F and one for temperatures above 32° F (fig. 2). The temperature correction was feasible only for temperatures above 32°F so we used the slope of the regression line, 0.52 K ohm per degree, as the temperature correction factor.

3. Using this correction factor, all resistance measurements taken in the

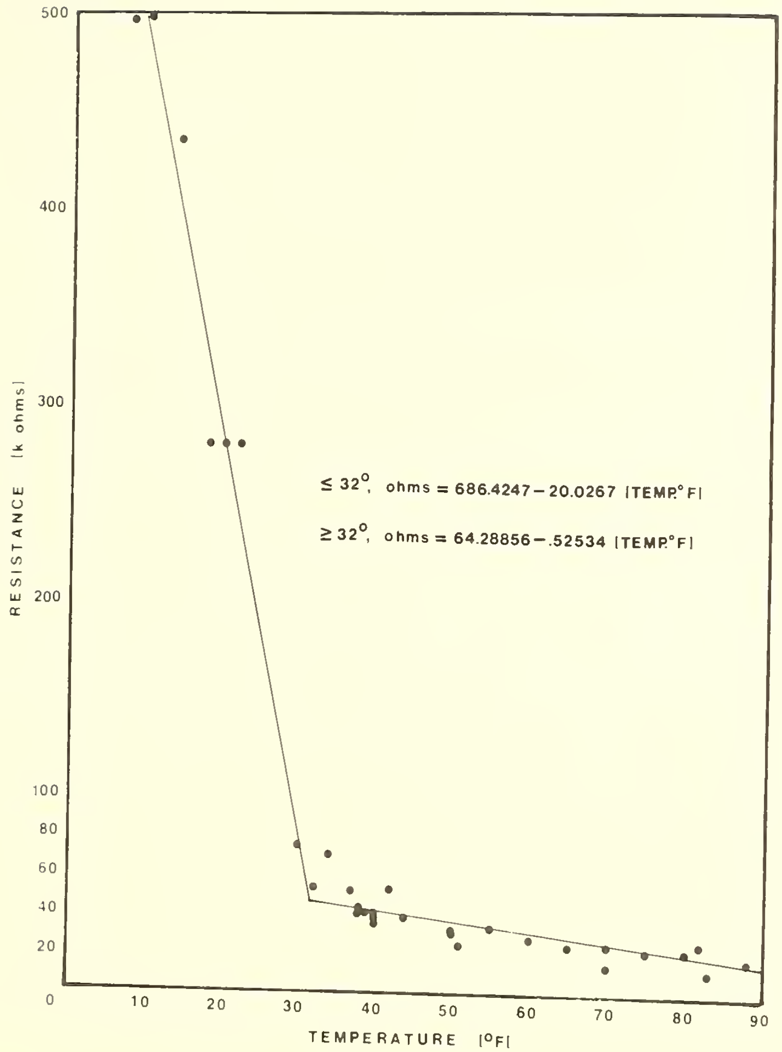

Figure 2.--Effect of temperature on resistance to pulsed direct current. Below about 32° F the effect is marked (20 K ohms per degree); above 32° F the slope is more gentle (0.5 K ohm per degree), but significant. The relation is similar to that reported in red pine, white spruce, and poplar (Glerum 1969).

nurseries were adjusted to a standard temperature of 68° F (20° C).

RESULTS AND DISCUSSION

ER Patterns In Deciduous Species

Several general patterns of ER were apparent in the nine hardwood species probed (fig. 3):

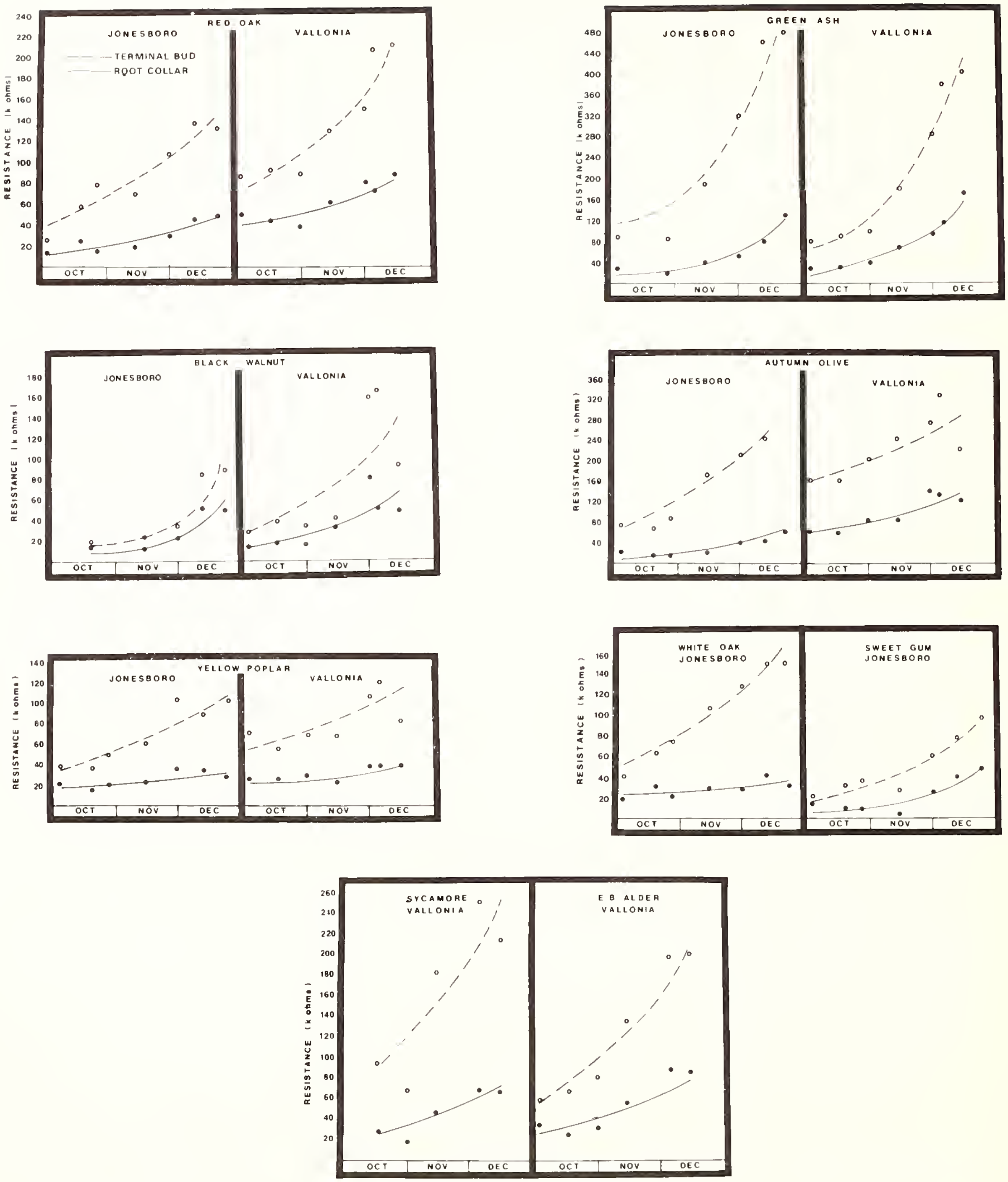

Figure 3.--Patterns of resistance to pulsed current at the terminal bud and root collar of nine hardwood species during the fall of 1977. Each point is the mean resistance of 15 seedlings adjusted to a standard temperature of 68° F (20° C). Regression curves were fitted to the data using the equation $Y = ab^X$, where Y is resistance and X is days from October 3.

1. ER was higher at the terminal bud than at the root collar.

2. An upward inflection in the terminal bud ER curve occurred 2 to 4 weeks earlier than it did in the root collar curve.

3. ER's varied more at the terminal bud than they did at the root collar.

4. In most species, a substantial change in resistance occurred in late October to early December, which appears to correspond to the onset of dormancy (table 1).

Table 1.--Coefficients for regression equations and standard errors of estimate, $Y = ab^X$ where Y = resistance in K ohms and X = days after October 3

Nursery	Species	Root collar a	Root collar b	Root collar SE_E	Terminal bud a	Terminal bud b	Terminal bud SE_E
Jonesboro	Black walnut	8.9607	1.0129	4.1830	10.4729	1.0184	7.9452
	Red oak	11.3092	1.0160	9.8131	37.8749	1.0148	24.1734
	Yellow poplar	16.3640	1.0079	7.3515	31.7194	1.0136	15.8749
	Green ash	8.3274	1.0300	18.1893	55.5371	1.0250	54.6387
	Autumn olive	8.4670	1.0221	10.7029	54.3970	1.0194	44.6598
	White oak	20.6170	1.0063	8.9340	46.4980	1.0141	25.8112
	Sweetgum	3.5796	1.0292	8.2057	15.1831	1.0204	17.6516
	Eastern white pine	23.3001	1.0131	22.1099	28.5814	1.0140	27.8843
	Loblolly pine	16.1076	1.0127	18.7533	24.2094	1.0160	20.5958
Vallonia	Black walnut	12.9403	1.0198	17.7498	23.7246	1.0217	39.7755
	Red oak	34.4475	1.0109	17.8700	61.2067	1.0150	39.3966
	Yellow poplar	22.4135	1.0067	11.6239	51.0337	1.0096	24.5215
	Green ash	12.1920	1.0312	31.7596	46.6690	1.0273	20.1416
	Autumn olive	47.4424	1.0132	37.7255	151.3565	1.0077	64.9895
	Sycamore	15.7395	1.0187	21.2089	62.2263	1.0168	53.6229
	European black alder	21.0325	1.0182	19.5191	47.1867	1.0177	32.0176
	Eastern white pine	54.4737	1.0017	23.4582	52.3812	1.0071	28.4075
	Red pine	46.7596	1.0079	24.5925	44.1953	1.0110	28.4600
	Scotch pine	18.9715	1.0124	14.8850	20.2895	1.0145	20.9310

Individual species varied in the point of inflection of the resistance curve, slope, date of change, and magnitude of resistance. Yellow-poplar increased slowly in resistance compared to other species, and both green ash and autumn olive showed generally higher resistances.

The actual resistance on a particular date differed at the two nurseries; however, it is the change in resistance that we are interested in. Specifically, it is the time when resistance changes significantly that may

indicate dormancy.

As one would expect, the greater the variability among seedlings and sample dates, the greater the change in resistance required to be significant and the later lifting may begin as indicated by ER. As measuring conditions and technique become more refined, variability will be reduced and the method will be more sensitive. Some species appear to vary more than others, e.g., black walnut and sycamore at the Vallonia nursery (fig. 3). Other species, e.g., yellow-poplar, show such a slow rate of increase in resistance that the present instrument and method may not work to detect dormancy.

ER Patterns in Coniferous Species

In contrast to the hardwoods, the increase in resistance at the terminal bud in conifers was more gradual and variable (fig. 4). With the possible exception of loblolly pine, there may not be enough change in resistance by mid-December to detect a significant increase. Perhaps the stability of the conifer curves is related to the frequency of introduced current. According to Glerum and Krenciglowa (1970), tissues with large cells (as in conifer phloem-cambium tissue) have larger membrane capacitances than those with small cells. Thus, because of a larger reactive component, introduction of lower frequency current should result in high resistance.

We emphasize that this paper reports preliminary findings. We will not attempt to infer when the seedlings are ready for lifting from the ER curves. Because the study included no measure of actual dormancy status of the seedlings we probed, e.g., forcing in the greenhouse or oscilloscope observations, we cannot specifically state that the seedlings entered dormancy at the times suggested by the resistance curves. The time seedling ER increased sharply appears to coincide with the time we expected the seedlings to be entering dormancy. However, during the fall many independent physiological changes occur in plants, and any one of them may be correlated with changes in ER. Because ER of plant tissue is determined by concentrations of mobile cations, it is possible that changes in it are the result of changes in the mobility of cations associated with hardening processes, i.e., changing from an unbound to a bound state, rather than translocations. What this suggests is that ER may be detecting the progress of other physiological processes, such as tissue hardening, but still may be strongly correlated with and indicative of dormancy.

FACTORS INFLUENCING SHIGOMETER READINGS

During the course of the study we identified a number of variables that affect ER measurements. This resulted in several modifications of our equipment and refinements of our technique.

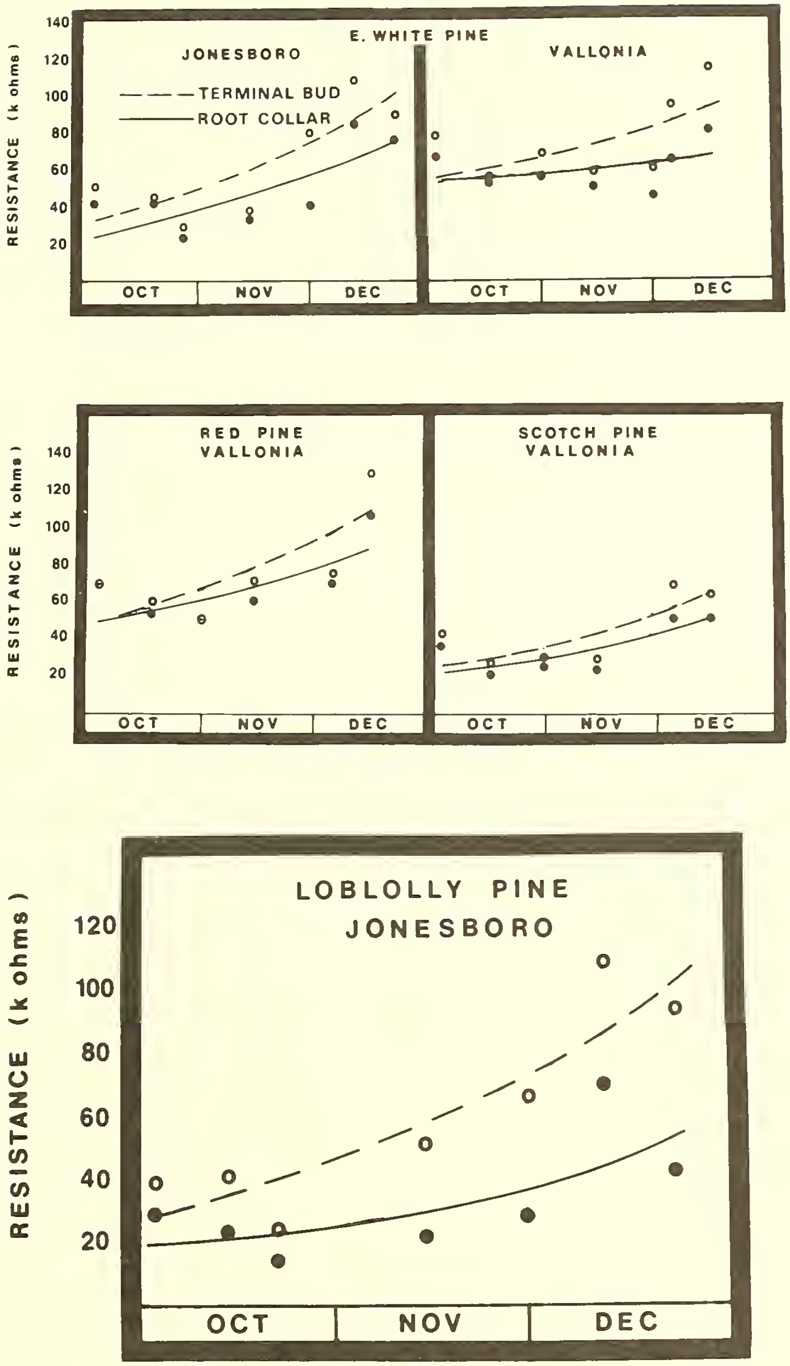

Figure 4.--Patterns of resistance to pulsed current at the terminal bud and root collar of four coniferous species during the fall of 1977. Each point is the mean resistance of 15 seedlings adjusted to a standard temperature of 68° F (20° C). Regression curves were fitted to the data using the equation $Y = ab^X$, where Y is resistance and X is days after October 3.

Temperature

The most obvious variable is temperature. Lowering the temperature lowers the activity of ions along the circuit. Although the temperature correction discussed earlier was effective in reducing variation, there are several other temperature effects:

1. The temperature correction was based on black wlanut seedlings and may not be applicable to other species.

2. It would be preferable to measure tissue temperature, rather than air temperature, because there is undoubtedly a lag between the two.

3. Weather fluctuations, specifically weekly temperature and rainfall patterns, affect ER both directly and indirectly. We can correct for direct temperature effects. However, sharp increases or decreases in temperature indirectly affect resistance through their effect on seedling physiological processes--specifically those affecting the mobility and activity of ions.

4. Measurements should be taken when temperature is stable and closest to 68° F.

Resistance Meter Ranges

The early fall measurements were taken with the 0 to 50 K ohm range. When resistance increased, we changed to the 0 to 500 K ohm range. Even with rezeroing the meter when changing ranges, we found a discrepancy between readings taken with the two meter ranges. This is due to the fact that the pulse resistance meter (fig. 1) is most accurate near full scale deflection (far right). To reduce error from this source, we modified our Shigometers to include a 250 K ohm range, which allowed us to take all of the measurements during the transition period without changing to a higher range.

Seedling Caliper

When the probe needles protrude through the seedlings, larger caliper seedlings tend to give lower resistance readings. This is primarily due to (1) area of contact--the amount of tissue in contact with the needles, and (2) phloem thickness. Larger and more vigorous seedlings have thicker phloem. Carter and Blanchard (1978) found that phloem thickness is strongly and inversely correlated with ER in red maple. To reduce variation from this factor, we sampled seedlings of uniform caliper (6 to 10 mm at 3 cm above the root collar for most hardwoods) using probe needles 5 mm long so they were fully imbedded in most hardwood seedlings. We are considering going to still shorter electrodes because ideally we want to penetrate the cork cambium-phloem-vascular cambium-outer xylem region on one side of the seedlings.

Plant Water Content and Potential

Extreme scarcity of water usually does not occur in the nursery environment, but the degree of hydration and water potential vary daily, weekly, and seasonally. ER is inversely correlated with percent moisture content above fiber saturation point (about 30 percent). The pattern is similar to the temperature/ER relation, with the inflection at fiber saturation point (personal communication with Dr. Alex L. Shigo, Northeastern Forest Experiment Station, Durham, New Hampshire). Dixon *et al.* (1978) reported a strong inverse correlation (-0.94) between plant water potential and resistance in avocado and white spruce. To reduce the effect of weather fluctuations it is necessary to maintain adequate soil moisture and take measurements in mid-morning when both atmospheric stress and plant moisture stress are low. The influence of seasonal patterns in physiological processes on seedling moisture content and water potential and resultant effects on ER is unknown.

Plant nutrition

Because resistance to a pulsed electric current decreases as concentrations of cations increase, we could expect variations if nutrient uptake differs. Changes in soil fertility and soil moisture availability may result in corresponding changes in nutrient uptake. Moreover, seasonal changes in nutrient uptake occur. The relation between cation concentration and ER is similar to the temperature/ER relation; the inflection is at about 10^{-6} M (personal communication with Dr. Alex L. Shigo). Normally fertilizer is not applied in the fall and soil moisture is adequate, so we would expect little variation in input of cations into the seedlings. However, we may find that seedling resistance readings vary among nurseries and years because of differences in soils and climate.

Variation Among Seedlings

Because of competitive differences and other inherent factors, the ER will vary among seedlings of one species. A recent sampling experiment indicated that a sample of 27 seedlings is needed. Standardization of measuring conditions and refinements in the instrument and techniques will reduce the number of samples needed.

CONCLUSIONS

The pattern of increasing resistance to pulsed electric current appears to coincide with the onset of dormancy in most of the deciduous but not the coniferous species probed. The pattern is detectable earlier and more distinctly at the terminal bud than at the root collar. In addition to seasonal physiological changes, ER varies with a number of environmental and physiological factors--including water content, water potential, temperature, and ion concentration.

The important point is that ER measurements must be used cautiously to be sure that changes in resistance are a true reflection of seasonal physiological changes rather than daily thermal or water potential trends. Additionally, studies of ER to detect dormancy should correlate readings with some measure of the actual dormancy status of the probed seedlings.

We are optimistic that a convenient method to correct or compensate for temperature will be found and measuring conditions and technique will be refined so that ER can be used to detect dormancy in nursery stock.

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ENDOMYCORRHIZAL INOCULUM IMPROVES GROWTH OF NURSERY-GROWN SWEETGUM SEEDLINGS

Richard O. Barham[1/]

Abstract.--Sweetgum seedlings grown on fumigated seedbeds under operational conditions in two southern forest nurseries showed significant growth increases when inoculated with an endomycorrhizal fungus. Height growth, root collar diameter, and endomycorrhizal infection of inoculated seedlings were respectively 37, 25 and 75 percent greater than noninoculated seedlings.

Additional keywords: *Liquidambar styraciflua*, *Glomus mosseae*, endomycorrhizae, height growth, root collar diameter, soil fumigation.

INTRODUCTION

Economic demands for quality southern hardwoods have increased efforts to regenerate certain species artificially. Sweetgum (*Liquidambar styraciflua* L.) has proven to be one of the most potentially desirable species due to its adaptability, growth rate, and wood quality.

A major deterrent to successful establishment of sweetgum plantations has been an inability of nurseries to consistently produce quality seedlings. One possible explanation for "poor" seedling quality may be a lack of beneficial endomycorrhizal fungi. The common practice of nursery seedbed fumigation appears to reduce fungal populations and adversely alter the development of endomycorrhizae (Filer and Toole 1968).

Bryan and Ruehle (1976) showed in a greenhouse study that sweetgum seedlings grown in fumigated soil and inoculated with *Glomus mosseae* (Nicol. and Gerd.) (Gerd. and Trappe) grew significantly faster than those in nonfumigated soil. Because of the apparent benefits of endomycorrhizae, a study was established to determine what effect artificial inoculation of *G. mosseae* would have on sweetgum seedlings grown under operational conditions in two southern forest tree nurseries.

METHODS

Prior to plot establishment, seedbed areas were fumigated in March, with approximately 450 kg/ha of methyl bromide (Dowfume MC-2^{R})[2/]. Seedbeds were developed and the study was installed in a randomized complete block design

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2/ Mention of trade name is solely to identify material used and does not constitute endorsement by International Paper Company.

with six replications in each nursery. Four treatments consisted of a control and three levels of *G. mosseae* inoculum composed of spores, chopped sorghum roots and soil from greenhouse pot cultures. Inoculum levels were calculated on a dry weight basis and were approximately 2.1, 6.2, 12.4 kg/m^2 respectively. Inoculum was spread evenly over the 5.6 m^2 (15 linear bed feet) plots and chopped into a depth of 10.2 cm (4 inches). Control plots received no inoculum.

Sweetgum seed from a common source were planted by the respective nursery personnel for 8 to 10 seedlings per square foot and treated just as the adjacent operational crop for the remainder of the growing season. Soil samples were taken throughout the growing season to determine pH, organic matter, Ca, P, K, Mg, and Mn.

Six weeks after planting and every three weeks thereafter, until termination of the study, seedlings were sampled to determine height growth, root collar diameter and/or endomycorrhizal development. Root segments were removed from the root systems of sample seedlings. These segments were cleared and stained according to the procedure of Phillips and Hayman (1970) and examined microscopically to determine endomycorrhizal infection. The percentage of infection of seedling roots was determined by comparing numbers of infected segments with numbers of noninfected segments.

RESULTS

Sweetgum seedlings inoculated with *G. mosseae* showed significant advantages over noninoculated seedlings when grown in fumigated nursery soil in the spring (Table 1). Inoculated seedlings were approximately 37, 25 and 75 percent greater than noninoculated seedlings in height, root collar diameter, and endomycorrhizal infection respectively.

Table 1.--Analysis of combined data from Columbia and Winona Nurseries.

		Nursery		Treatment[a/]			
Variable	Week	Columbia	Winona	I	II	III	Control
$\bar{x}$ height (cm)	15	13.66	23.52	19.51	19.85	19.96[b/]	15.04
	33	22.50	55.32	43.28	41.48	40.53	30.36
$\bar{x}$ root collar (mm)	15	2.48	2.80	2.75	2.74	2.85	2.20
	33	5.13	6.20	5.98	5.89	6.04	4.75
% myc. inf.	15	47.80	63.77	71.53	72.60	71.18	7.59
	33	50.35	72.75	67.25	73.93	65.76	39.27

a/ Treatment inoculum levels I, II, and II were 2.1, 6.2, and 12.4 kg/m^2 respectively. Controls received no inoculum.

b/ Numbers connected by a straight line are not significantly different at 95% confidence level using Tukey's ω-procedure.

Fumigation of the nursery soil apparently eliminated the majority of endomycorrhizal fungi. This was evidenced by the fact that controls remained basically nonmycorrhizal until about the twelfth week following planting. Once noninoculated seedlings became infected with natural inoculum their growth rate was approximately equal to that of inoculated seedlings. Noninoculated seedlings were never able to make up the early growth lost due to a lack of endomycorrhizae early in the growing season.

Treatment effects were practically the same at both nurseries, although seedling quality varied by nursery. No significant differences were observed between inoculated treatments, which indicates that relatively low levels of endomycorrhizal inoculum were sufficient to stimulate early growth of seedlings.

DISCUSSION

Growth stimulation of sweetgum seedlings indicates that this species ~~is~~ highly dependent upon endomycorrhizae. These endomycorrhizal fungi are greatly reduced by soil fumigation in the spring. Fall fumigation may be better than spring fumigation because of the additional time allowed for soil conditions to stabilize.

Inoculation of sweetgum seedbeds proved beneficial when following spring fumigation. The feasibility of this practice at present is questionable for large seedling crops. Perhaps a better solution would be to have enough nursery space to fumigate and cover crop a year prior to planting. Depending upon the cover crop selected, endomycorrhizal fungi could possible be manipulated to produce optimum population levels.

Seedling quality varied by nursery while the treatment effects remained the same. Soil analyses revealed a possible phosphorous (P) deficiency in the hardwood seedbeds at the Columbia nursery. The P level would probably have been adequate for pine, but hardwoods seem to require about twice as much P for maximum growth.

The inconsistency of production of quality hardwoods in pine oriented nurseries may be a combination of minimal nutrients and fumigated soil. Minimal nutrients may become more of a growth factor when soils are fumigated and endomycorrhizal fungi are eliminated.

Seedling quality in any nursery is the end result of a number of contributing factors. Endomycorrhizae appears to be one of the main factors affecting the growth and development of sweetgum seedlings. Therefore, anything a nurseryman can do to improve early endomycorrhizal development in his sweetgum seedlings the better chance he has of a successful crop.

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NATIONAL *PISOLITHUS TINCTORIUS* ECTOMYCORRHIZAE NURSERY EVALUATION

Charles E. Cordell, Robert L. Anderson, and Donald H. Marx[1/]

ABSTRACT

During the past several years, the U. S. Forest Service has been conducting extensive research and field application studies concerning the practical application of the ectomycorrhizal fungus, *Pisolithus tinctorius*, to bare-root and container seedling nurseries. Positive results, involving increased ectomycorrhizal development on seedling feeder roots, increased seedling biomass, and decreased cull percentages have been obtained on a variety of conifer and some hardwood seedling species over a wide geographic range in the United States. In 1978, the National *P. tinctorius* mycorrhizae evaluation was expanded to include 33 bare-root nurseries in 28 states along with container seedling studies in 8 states (including Hawaii) and Canada. The objective of this evaluation was to compare the effectiveness of *P. tinctorius* inoculum produced by the Mycorrhizal Institute - Athens, GA and Abbott Laboratories - Chicago, IL for ectomycorrhizal seedling feeder root formation, seedling growth and quality, and tree survival and growth in subsequent field outplantings. Preliminary evaluation results show the Abbott *P. tinctorius* inoculum to be nearly comparable to the Georgia inoculum in producing ectomycorrhizae on a variety of conifer and some hardwood (oaks) species in both bare-root and container seedling nurseries. Consequently, these results could represent a significant potential increase in nursery seedling quality along with timber volumes. Barring unforeseen problems, Abbott Laboratories anticipates the commercial availability of *P. tinctorius* inoculum in 2-3 years.

Additional keywords: Forestation, bare-root nurseries, container seedlings, adverse sites, windbreaks, shelter belts, Christmas trees, hardwoods, conifers, *Abies concolor, A. fraseri, Pinus banksiana, P. clausa, P. echinata, P. elliottii, P. nigra, P. palustris, P. ponderosa, P. strobus, P. sylvestris, P. taeda, P. virginiana, Quercus macrocarpa, Picea mariana, Pseudotsuga menziesii.*

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INTRODUCTION

The mycorrhizal fungi are the beneficial fungi in forest tree nurseries, field forestation, and natural stands. Two primary types of mycorrhizae are the ectomycorrhizae and the endomycorrhizae. The ectomycorrhizae form a rather conspicuous fungus mantle on the surface of the feeder roots primarily on conifers (pine, fir, spruce, hemlock, larch, Douglas-fir) along with some hardwoods (oaks, birch, eucalyptus). The endomycorrhizae develop within the root cortical cells primarily on hardwoods such as walnut, poplar, maple, sweetgum, sycamore, and ash. The ectomycorrhizae also produce a variety of fruiting bodies such as puffballs and mushrooms above ground; their spores are wind-disseminated. However, the endomycorrhizae produce their spores on infected root surfaces below ground and, consequently, are limited to localized distribution in the soil by water, soil tillage, etc. Both types of mycorrhizae occur on a wide variety of plant hosts throughout the temperate zones of the world; their occurrence constitutes the rule rather than the exception in nature.

PAST RESEARCH AND FIELD EVALUATIONS

During the past several years, the Mycorrhizal Institute of U. S. Forest Service at Athens, Georgia, has been conducting extensive research on mycorrhizae (1). This research has centered around one particular ectomycorrhizal fungus, *Pisolithus tinctorius (P.T.)*, and its application to forest tree nurseries and field forestation. Based on the successful results obtained from these pioneer laboratory and greenhouse studies, field evaluations were initiated in selected southern nurseries to evaluate the effectiveness of *P.t.* artificial inoculations in producing tailored ectomycorrhizae on a variety of seedling hosts and geographic locations in the Southeast (2). The effectiveness of *P.t.* on seedling growth and quality along with tree survival and growth responses in followup outplantings were also evaluated. Artificial seedbed inoculations with *P.t.* spores and a mycelium-vermiculite-peat inoculum were evaluated in three southern nurseries--one each in North Carolina, Georgia, and Florida (2).

Results obtained from these studies were highly successful. Significant increases in ectomycorrhizal production along with seedling growth and quality were obtained on the majority of the *P.t.* inoculated plots as compared with uninoculated check plots. However, the *P.t.* mycelium-vermiculite-peat inoculum was more effective than the spores. Seedling fresh weights on loblolly pine (*Pinus taeda)*, slash pine *(P. elliottii)*, sand pine *(P. clausa)*, Virginia pine *(P. virginiana)*, and eastern white pine *(P. strobus)*, were increased over 100 percent in one growing season - the normal seedling rotation for these southern hard pines except for eastern white pine which is 2 years. The common indigenous ectomycorrhizal fungus, *Thelephora terrestris*, produced abundant mycorrhizae (50+ percent) on the uninoculated plots. This mycorrhizal fungus accounts for 75+ percent of the ectomycorrhizae on pine seedling roots in southern nurseries. Followup field outplantings were established in North Carolina and Florida to determine the effects of different *P.t.* ectomycorrhizae levels on tree survival and growth. Significant increases in plot volume (tree survival X ht. X basal diameter^2) have been realized in two

sites each in North Carolina and Florida after 4 years in the field. An average increase in plot volume of 46 percent has been obtained on plots planted with seedlings inoculated with *P.t.* mycelium in the nursery as compared with the check plots planted with uninoculated (natural *T. terrestris* inoculated) seedlings (3).

NATIONAL *P.t.* ECTOMYCORRHIZAE NURSERY EVALUATION - 1977

Following these results, Abbott Laboratories in Chicago, Illinois, became very interested in the commercial production and practical application of *P.t.* for forest tree nurseries and field forestation. Subsequently, a National *P.t.* ectomycorrhizae nursery evaluation was initiated in the spring of 1977. This is a cooperative evaluation by the Mycorrhizal Institute, the Southeastern Area, Forest Insect and Disease Management Staff, Abbott Laboratories, and various state and industry agencies. The 1977 evaluation was conducted in 17 nurseries in 15 states from Virginia to California and involved seven species of pines along with white fir (*Abies concolor*) and Fraser fir (*A. fraseri*). The objectives of this evaluation were to compare the effectiveness of *P.t.* mycelium-vermiculite-peat inoculum produced by the Mycorrhizal Institute, with that commercially produced by Abbott Laboratories for mycorrhizae production, seedling growth and quality, and tree survival and growth in tree nurseries and field plantings. Results obtained with the Georgia *P.t.* inoculum were highly successful on all host species in all nurseries (table 1). Artificial seedbed inoculations with this inoculum source produced an average of 25 percent *P.t.* ectomycorrhizae, increased seedling fresh weights 13 percent, and decreased seedling culls 32 percent on the seven species of pines in the 17 nurseries. Positive *P.t.* ectomycorrhizae development was also obtained on the two species of fir but these results are not included in this summary. Results obtained with the Abbott *P.t.* inoculum (high rate: 150 ml/ft^2 in seedbeds) were considerably less effective than the Georgia *P.t.* inoculum (table 1). Seedbed inoculation with this inoculum source produced an average of 4 percent *P.t.* ectomycorrhizae on the same 7 species of pine in the 17 nurseries. However, there was no difference in seedling fresh weights and very little difference in seedling culls using this inoculum source as compared with the uninoculated check plots. The Abbott *P.t.* inoculum did produce some degree of ectomycorrhizae on all the seven pines and two fir species inoculated in the 17 nurseries. Similar comparative results between the Georgia and Abbott *P.t.* inoculum sources were also obtained in a companion container seedling evaluation conducted in five locations from North Carolina to Oregon. Subsequent discussions with scientists at Abbott Laboratories revealed probable production problems with the initial *P.t.* inoculum batches in 1977. These problems have since been identified and, hopefully, corrected.

EXPANDED NATIONAL *P.t.* ECTOMYCORRHIZAE NURSERY EVALUATION - 1978

In 1978, the National *P.t.* mycorrhizae nursery evaluation was expanded to include 33 bare-root forest tree nurseries in 28 states from Delaware to Florida and Oregon. Seedling species involved include 11 species of pines along with two varieties of Douglas-fir (*Pseudotsuga menziesii*) and Fraser fir. The evaluation objectives are the same as

TABLE 1.--Overall summary of 1977 test in 17 nurseries (1-0) using laboratory (Ga) and Abbott (Abb) produced vegetative inoculum of *Pisolithus tinctorius* (*Pt*) to form ectomycorrhizae on seven species of pine.

Treatment	Seedlings fresh wts. (gm) Top	Roots	Total	% Ectomycorrhizae by: Pt	Other	Total	Percent of seedlings with *Pt*	Percent cull seedlings	Total No. *Pt* fruit bodies
Ga 100	12.2	4.8	17.0	25	12	37	93	16.1	43
Abb 150	10.8	4.2	15.0	4	26	30	26	23.3	12
Abb 100	10.8	4.2	15.0	3	27	30	23	22.0	3
Abb 50	10.5	4.1	14.6	3	29	32	19	23.7	8
Control	10.8	4.2	15.0	<1	30	30	3	23.7	1
% increase of Ga 100 over control	13.0	14.3	13.3	N.A.	N.A.	23	N.A.	32.1	N.A.

for the 1977 evaluation - comparison of Georgia and Abbott *P.t.* inoculum effectiveness for mycorrhizae feeder root formation, seedling growth and quality, and tree survival and growth in nursery seedbeds and field plantings. As in previous nursery seedbed evaluations, randomly selected prefumigated seedbed plots were inoculated with either the Georgia or Abbott *P.t.* mycelium-vermiculite-peat inoculum immediately prior to planting. Prefumigation with soil fumigants equivalent to methyl bromide - 98% + chloropicrin - 2% and methyl bromide - 67% + chloropicrin - 33% has been mandatory in obtaining successful *P.t.* nursery seedbed inoculations. The dried inoculum mixture (approximately 12 percent moisture content) was sprinkled evenly on 4 X 4 ft (16 ft^2) plots at four dosage rates - Georgia - 100 ml/ft^2, Abbott - 200, 100, 50 ml/ft^2. The inoculum was then chopped into the upper 3-4 inch soil surface with a garden tool. Each of the five treatments - four *P.t.* treatments and one check -were replicated five times in a randomized 5-block design. Following the inoculation, conventional seeding, mulching and all other nursery cultural practices were maintained as usual. The nursery phase of this evaluation is scheduled for 1 to 3 years, depending on the rotation length of the seedling host species. Followup field outplantings are also scheduled for a 5-year duration to compare the relative effectiveness of various degrees of Abbott and Georgia *P.t.* mycorrhizae feeder root formation on tree survival and growth. A companion container seedling study, also using the Abbott and Georgia *P.t.* inoculum, with similar objectives and followup outplantings is also being conducted in eight states (including Hawaii) and Canada during 1978.

SUMMARY AND CONCLUSIONS

1. The ectomycorrhizal fungus *Pisolithus tinctorius* can be successfully artificially inoculated into prefumigated nursery seedbeds and greenhouse containers on a wide variety of conifer (pines, firs, Douglas-fir) and some hardwood (oaks) species and in a wide geographic range within the United States. The Georgia *P.t.* inoculum has produced 20 percent or more *P.t.* ectomycorrhizae on the feeder roots of bare-root Fraser fir in western North Carolina, several species of pine throughout the south, and ponderosa pine *(P. ponderosa)* at Placerville, California, along with container-grown jack pine *(P. banksiana)* in Maine and Canada, several species of pine in Nebraska and longleaf pine (*P. palustris)* in Louisiana and Georgia.

2. Artificial inoculations with the Georgia *P.t.* mycelium-vermiculite-peat inoculum significantly increased seedling growth and quality (fresh weights) in nursery seedbeds along with significant increases in tree survival and growth in field plantings. These results suggest significant potential economic benefits to forest tree nurseries and field forestation. For example, the 32 percent reduction in cull seedlings obtained in the 17 nurseries during 1977 would result in the production of 85 million more plantable seedlings annually in the present 55 southern nurseries. Based on present seedling values ($12/M), this represents an annual seedling monetary benefit of $1,020,000. The 46 percent increase in plot volume realized on the Georgia *P.t.* treatment plots on the four outplanting sites in North

Carolina and Florida after 4 years in the field represents a considerably larger potential benefit to field forestation. This increase in plot volume represents a potential annual increase of 17.25 million cords (1.55 billion ft^2) in pine wood volume in 13 southern states from Virginia to Texas. Based on present round wood values, this represents an annual potential increase in southern pine wood volume values of $345 million.

3. Although the results obtained with the Abbott *P.t.* inoculum were considerably less successful than those with the Georgia *P.t.* inoculum in 1977, the production of some *P.t.* mycorrhizae in practically all the nurseries inoculated with this commercially-produced inoculum is highly significant and gratifying. Preliminary mid-season examinations of the 1978 nursery studies show the Abbott *P.t.* inoculum to be nearly comparable to the Georgia *P.t.* inoculum in producing ectomycorrhizae on a variety of conifer species in several bare-root nurseries. Results obtained from the 1978 container seedling evaluation also show the Abbott *P.t.* inoculum as comparable to the Georgia *P.t.* inoculum in the production of *P.t.* mycorrhizae on a variety of seedling hosts from such diverse locations as Canada, Maine, Nebraska, and Louisiana. Over 15 percent *P.t.* ectomycorrhizae have been produced by the Abbott inoculum on shortleaf pine *(P. echinata)* in Louisiana, bur oak *(Quercus macrocarpa)* in North Dakota, Austrian *(P. nigra)*, Ponderosa and Scotch *(P. sylvestris)* pine in Nebraska, and on jack pine in Canada and Maine.

4. Consequently, those of us who have been working on this project for the past several years are now optimistic concerning the practical application of the *P.t.* ectomycorrhizal fungus to nursery and container-grown conifer seedlings for the production of "tailored" seedling products. The "tailored" seedling product may have a variety of forestry-related uses such as adverse site forestation, windbreaks or shelter belts, seed production areas, and Christmas trees along with increased timber volumes. Abbott Laboratories shares this optimism with us and has allocated a considerable effort in technology development and financial expenditure for the commercial production of this mycorrhizal fungus product. Barring unforeseen problems, Abbott anticipates the commercial availability of the *P.t.* inoculum in 2-3 years.

5. Future followup evaluations are being planned by the Southeastern Area concerning the practical inoculation of bare-root nursery seedbeds utilizing a modification of conventional seeding or mulching equipment.

6. Meanwhile, the Mycorrhizal Institute, along with Abbott Laboratories, are continuing and expanding their cooperative efforts with various Federal, State, industry, and university agencies in widespread locations throughout the United States and several foreign countries concerning the research, development, and application of other suitable ecto- and endomycorrhizal fungi in both bare-root and

container nurseries. The Mycorrhizal Institute has recently expanded its research and development effort to include the endomycorrhizae of specific species of hardwoods.

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HYDROMULCHING OPERATIONS AT WEYERHAEUSER'S MAGNOLIA NURSERY

R. P. Plyler

Abstract: Hydro-mulching, using wood fiber, has proven to be an effective method of covering pine seed in nursery beds to assure more uniform germination, less weeds, and less contagious pathogens that are associated with other types of mulch. It also helps to assure less seed and seedbed erosion.

Forest seedling nurserymen, for many years, have searched for an effective material to protect seed and seed beds from erosion. In their search, many things have been used, i.e., burlap, pine straw, sawdust, bark, agricultural crop residue, netting, and wood fiber.

Hydro-mulching, using wood fiber mulch as seed bed covering, was introduced to forest nurseries about a decade ago.

The wood fiber mulch is clean, uniform in size, non-toxic, free of weed seed and fungi that may be present in some other materials.

The Magnolia nursery has used fiber mulch since the beginning of its operation in 1972. That year, with normal start-up problems and near normal weather conditions, the fiber mulch looked good enough to try again.

In 1973, having heard of a soil binder that might aid in holding fiber in place, a test section was set up. This test showed promising results, with a saving of 25 to 30 seed per bed foot over that without binder.

After this test, fiber mulch with binder became operational. Some areas held well, and others did not. It was discovered that the mulch needed a curing time before a heavy rain. Beds that had 48 to 72 hours curing time before a heavy rain stayed in place better than those receiving rain shortly after sowing.

It was found that covering seed lightly with soil before the mulch was applied, aided in keeping more seed in place. If seed is sown on top of the soil, some may be floated to the top of the mulch from force of the mulch hitting the bed.

The present method used is to mix 250-300 pounds of fiber mulch, 10 gallons of binder, and enough water to total 800 gallons of mix, agitating continually. The above slurry mixture is then applied on freshly sown beds at the rate of one tankful/2000 lineal bed feet. This equates to approximately 1500 pounds per bed-acre.

In 1978, two more reasons for mulching seed beds have been noted. Test beds were not mulched, and a late frost followed by high cold winds occurred during germination. Seed not mulched received more damage than those with mulch.

With the extreme hot weather this summer, it is obvious that where fiber mulch is still present, seedlings are taller, greener, and have a better root system.

Method of application is with the trailer type hydro seeder/ mulcher, equipped with deflector boards. The machine has an 800 gal. tank, with paddle type agitators and by-pass return, which keeps fiber mulch in suspension.

Seed beds are prepared, seed sown, and lightly covered with soil. The mulch is applied immediately following sowing, and due to other cultural practices, watered with one-half inch water by irrigation.

ORGANIC ADDITIVES at WIND RIVER NURSERY

DAVID W. DUTTON

ASSISTANT NURSERYMAN

WIND RIVER NURSERY

CARSON, WASHINGTON

U. S. F. S. R-6 GIFFORD PINCHOT NATIONAL FOREST

JULY 27, 1978

Wind River Nursery was established in the early 1900's to reforest some devastating burns in southwestern Washington.

We are located in Washingtonclose to the Columbia River about 60 miles east of Portland, Oregon at an elevation of 1100 feet. Our weather is mild with average annual temperatures being 48° and average annual rainfall being about 90 inches. We do have snowfall at the Nursery, but the past few years little snow has fallen. This has certainly helped our dormant lifting of seedlings in January and February.

Wind River Nursery now produces and ships about 30 million seedlings annually. This was our record season with over 35 million conifer seedlings being packed and shipped. This has been accomplished on only 120 acres. You can then readily see that we have a huge problem of being short of ground and not being able to use the land properly. We are confident of obtaining an additional 60 acres in the near future.

Thus, to handle this problem we knew we had to really work hard and take care of our land. We feel we have been successful with annual soils testing, proper fertilizer, and lots of good organic material. It's exciting and I know we have only scratched the surface.

Portions of our Nursery have been tree farmed since 1909, close to 70 years. So naturally in some areas our organic content was getting below the required amount for growing conifer trees. We believe our soils organic content should be a least 3% and pH should be around 5.5. For us, this is a great stride forward since we started at an organic content of 1.8 - 2.2. Past years reveal that the Nursery has added sawdust, peat, cow and chicken manure as a means of supplying organic materials and maintaining soil fertility. Presently we use sawdust, peat, green manure, Milorganite (fertilizer produced from activated sewage), and our newest material - Fish Digester Sludge. We are also studying in cooperation with Crown Zellerbach, the applicability of wood and pulp sludge mixture as a mulch on top, incorporated into the soil or a combination of both to grow conifer seedlings. In additions, we have recently located two sources of chicken maure and are presently using it. Believe it or not, we had a hard time locating a good source of available sawdust. We didn't give up however, and have now found a cheap, local source. We continually are on the lookout for new organic material. At the present time, we are looking at Municipal Sludge. I will discuss primarily the Fish Sludge, Milorganite, and Municipal Sludge, as part of our Nursery fertilization program. They should be of most interest to you as Nurserymen.

I have been involved in our fish sludge project quite closely. It's very interesting and exciting to me. We have been working with this for two seasons. When we first became involved in this project our thoughts were to use the Fish Sludge in our Nursery Fertilization Program strictly as a slow-released nitrogen supplement to the soil and as a soil conditioner. If it proved feasible, we would apply directly to the trees and cover crop: this we are now doing. Contrary to what you may think, this product is almost odorless. It has been run through a primary and secondary digester. Our Nursery folks call it "Super Sludge". Time will tell whether it really is.

We began hauling the sludge in mid April oflast year following consumation of a memorandum of understanding with the U. S. Army Corps of Engineers at Bonneville Dam.

I will now go into some slides to tell the Fish Sludge Story.

Bonneville Fish Hatchery

I will begin by telling you the fish effluent comes from the Bonneville Fish Hatchery run by the Fish Commission in Oregon. It's mostly water, fish droppings and feed. Next year the effluent will include eggs and blood waste residues from the spawning operation. Here's two slides of the hatchery. It is located right along the Columbia River with the Bonneville Dam and the south shore sanitary facilities run by the Corps of Engineers. This is the real exciting aspect of this project. You don't often see three agencies like the Forest Service, Fish Commission and the Corps of Engineers working together. We have worked hard to get this project underway beginning about 3 years ago.

Bonneville Dam and Columbia River

Some of you have seen this scene of Bonneville Dam and the "mighty beautiful Columbia". I put in these slides just to note that the fish or other raw wastes can't be dumped into the Columbia River any more and that is where we came into the picture. One of the Corps Engineers - thought it might be a good fertilizer for Wind River Nursery. They asked Stu Slayton our Nurseryman and he said yes - we would certainly give it a try.

Primary Digester

This primary Digester is located right next door from the Fish Hatchery at what is called the South Shore Sanitary Facility. The fish sludge and small amounts of domestic sewage arrives here first. It is 36 feet across and when filled it hold 102,000 gallons. Time spent here depends on per cent of solid material and amount of room available in the secondary digester. When the effluent leaves this primary digester it should be about 1½ - 2% in solid material.

Secondary Digester

The engineering firm of Kramer, Chin and Mayo did extensive studies on the best method of treatment for the fish sludge. They determined that aerobic digestion was the answer. Aerobic digestion is different from the more conventional anaerobic digestion used in most treatment plants. Both of the Bonneville digesters are open to the atmosphere and are constantly supplied with oxygen through blowers and mixers. These digesters produce no obnoxious odors or methane gas. If the sludge is allowed to sit for a day or two without supplying oxygen to it or mixing, the sludge will become vile and odorous.

Both treatment systems are designed to work together. The operation of the digesters calls for 16 hours of mixing and oxygen, then 6 to 8 hours of settling. At the end of the settling period, they will draw the clear liquid, (called supernatant) off the top of the digesters and pump it into the oxidation ditch and back into the system. It is virtually bacteria free and is eventually disposed of in the river.

We have looked into the possibilities of using the supernatant which we were told was rich in nitrogen. We haven't used it because there is too much water and little nitrogen. The two digesters in the system add flexibility, reliability and additional storage at the site.

The actual reasons for the two digesters are to: (1) Treat and decompose the sludge into an inert, stable material; and (2) to increase the solids concentration thereby reducing the volume of sludge to dispose of ultimately. When the sludge goes into the primary digester, it should be about ½ - 1% solids and when it goes to the secondary digester, it is about 2% solids. The sludge will be approximately 3.2% solids after it leaves the secondary digester (just a slight slurry). Our analyses to date reveal that the solid content has been from 2 - 2½%. We need to work on this aspect as we want to haul as much solid material as possible.

The secondary digester holds 189,000 gallons when filled. It takes about 8 - 20 days for the sludge to reach proper solid per cent before we haul to the Nursery.

South Shore Facility Operator

This is the fellow that operates this two million dollar Sanitation Plant. He is a wealth of information and has helped us tremendously. The secret of an operation of this magnitude is complete cooperation and open communication. This has certainly taken place in this project. The only complaint we have had is our trouble in interpretation of the analyses we get from the Corps. We have concentrated on this aspect and new feel more confident in analysing the test results.

Loading Sludge at Bonneville

Here you see the loading of the fish sludge at Bonneville. They have devised a special spout with a lock which works great. This truck is a rented tractor and the trailer is supplied by the Corps of Engineers. The Corps of Engineers in the agreement supplied all the equipment including two trucks, pump and hose, irrigation pipe and Rainbird sprinkler gun. This truck hauls 2,500 gallons and we usually haul four loads or 10,000 gallons a day. The distance to the Nursery is 25 miles, so our drivers needs to hustle. Last year we hauled over 400,000 gallons or enough to cover 40 acres, at a 10,000 gallons per acre application. Continued Hatchery expansion could easily double this figure in two years. This year the Hatchery lost most of their fish so we lost most of the sludge and hauled about 125,000 gallons.

Wind River Nursery

This is a picture of the Nursery looking toward Stevenson Ridge. Stock looks excellent this year. So I threw this in to boast a bit.

Tanker Being Hooked Up to the Pump

This is a close up of our 2500 gallon tanker being hooked up to our

pump. Our pump is a Wisconsin pump designed for a discharge pressure of 100 PSI (pounds per square inch) or 230 TDH and 136 gallons per minute. This system of having the pump mounted on a trailer has proven to be quite mobile and flexible in the Nursery. Our irrigation crew can easily change location between load deliveries. Presently we are looking for a 4 or 5000 gallon tanker trailer to use for fish and other sludges.

Close-Up of Pump Mounted on Trailer

Here's two close-up shots of the Wisconsin pump mounted on a trailer. It has a 3" suction and 3" discharge hose. We raised the pump 4 inches off the trailer floor. It saves knuckles and is easier to start.

Rainbird - Rain Gun

On this slide, you can observe the large Rainbird Gun Impact Sprinkler that sprays on the effluent. The gun can be set for full circle or close to an acre, a ½ circle or a ¼ circle. The head has a 0.69" straight bore nozzle with 23 degree trajectory. Design pressure at head is 90 PSI at 150' radius, and a flow of 136 gpm water. We operate the pump so the generated pressure at the head is about 55-60 PSI. Here it is set up in a ½ circle to apply the sludge on our cover crop of Austrian peas and oats.

Applying Fish Effluent

Next, we observe a series of 1977 slides showing sludge application in mid June to cover crop, 1-1 transplants and 3-0 Noble and White fir seedlings. The cover crop and seedlings were very green and lush. The cover crop crop exceeded 3 feet in height. This was our first application to our seedlings, although we did have prior approval from DOE and EPA to do so from the start. We preceded quite cautiously, because we didn't know how our Nursery workers and the general public would react. Everybody urged us to spray directly on the seedlings and cover crop. So we did right away. The effluent landing on the seedlings does not burn or damage the seedlings in any way from our current observations.

On this area we applied 10,000 gallons per acre. Presently we have doubled this amount and now apply 20,000 gallons per acre. Present analysis reveals we are applying 200 pounds of solid nitrogen per acre in a solution of 2 - 2½ % solids. It's also very possible to run the effluent through our irrigation systems.

Overall View of Tanker Pump and Supervisors Sizing Up the Situation

This project has created a lot of interest for everyone. We have had quite a few visitors and some media coverage. Public reaction has been very favorable to this project. I think one reason for this is our country's strong environmental concern. We are taking a product that was formerly wasted and causing pollution and now using it to grow a useful project. The White and Noble fir look excellent in this slide.

Driver Raring to go for another Load of Fish "Super Sludge"

This rental tractor cost us about $190.00 a week. Thus we kept it busy and averaged 50,000 gallons a week.

It is our hope that the Corps of Engineers can get us a 4000 or 5000 gallon tanker. Then we can really make it pay. Our rough calculations compute to a cost of about a penny a gallon. Presently other hatcheries and three cities, Cascade Locks, Hood River, Oregon and Washougal, Washington have inquired about us using their fish and human waste. We will probably start hauling from the Fish Hatcheries only after we have first fulfilled our Bonneville obligation.

At the peak of the fish rearing season in the spring, May and June, it appears that we need to remove at least 20,000 gallons a week to keep the Bonneville system running smoothly.

Wind River Nursery Scenes -- Bunker Hill and Bedhouses

In general, we are quite satisfied with our second year in the Fish Sludge business. It is still quite experimental and we intend to find out much more. Just last month we found out that the Sludge solid content can be raised even higher and thus we will haul about half as much water as we have done in the past. This has definitely encouraged us to stay in the Fish Manure business. I know you are interested in the amounts of metals and other minerals. Presently, the analysis indicates metal amount to be quite minimal. We are quite concerned with this aspect of the sludge and will continue to monitor it closely. The following page is a tabulation of early test results in 1977.

	COE Lab Sample Data 10 May '77	Columbia Lab Sample Data 10 May '77	COE Lab Sample Data 1 June '77	Recommended Quantities For Irrigation Water (Wet Weight Basis)
Total Solids	0.40%	3500 ppm = 0.35%	0.35%	--
Volatile Solids	62.1%	2188 ppm = 62.5%	60%	--
TKN	54 gms/kg	2.2 ppm = .002 gms/kg[1]	34 g/kg	(2.2 ppm)
Hg	6.006 mg/kg[2]	.027 ppm = .027 mg/kg	0.029 mg/kg	Not known.
P	-	.09 ppm = .09 mg/kg	51 mg/kg	-
Pb	0.25 mg/kg	.10 ppm = .10 mg/kg	0.89 mg/kg	5.0 mg/liter
Cd	0.075 mg/kg	<.01 ppm = <.01 mg/kg	0.25 mg/kg	.010 mg/liter
Zn	1.24 mg/kg	2.12 ppm = 2.12 mg/kg	3.95 mg/kg[3]	2.0 mg/liter 1.0 mg/liter on acid soils
K	17 mg/kg	7.0 ppm = 7.0 mg/kg	Trace	-
As	-	.004 ppm = .004 mg/kg	-	0.10 mg/liter
Cr	-	.10 ppm = .10 mg/kg	-	0.1 mg/liter
Cu	-	.51 ppm = .51 mg/kg	-	0.20 mg/liter

1/Is probably NO_3 nitrogen.

2/Highly variable test, possible error.

3/Appears to be highly questionable data.

MILORGANITE 6-2-0

I will continue on and discuss another product that we at Wind River Nursery believe is another good fertilizer and source of organic material. We continually see the excellent results it produces for us in larger and higher quality seedlings. It is better known as "Milorganite" 6-2-0 (Milwaukee organic nitrogen).

This organic fertilizer is produced by the Milwaukee, Wisconsin Sewerage Commission. Stu discovered this product when he was a Nurseryman back at Toumey Nursery in Michigan. He observed that it really made golf courses green and lush. Also that it must be quite pure. At Toumey, he obtained good results in producing quality seedlings. Upon arrival at Wind River in 1974, he soon realized that our soil was marginal as far as organic matter was concerned. Thus the use of Milorganite was born at our Nursery. The Nursery began by experimenting with various application rates in 1974 through 1977.

In the summer of 1976, we applied about 2000 pounds per acre to all 2-0 and 3-0 seedling in 2 - 3 applications. We tried to time this just before a rapid growth period. We use two Farmall Cut 140's with a small Gandy spreader to apply the Milorganite. In additions, we again conducted tests with various rates of application throughout the Nursery on all ages, classes and species.

The 2000 pounds per acre application appears to be the best over all rate to use. You can add more or less Milorganite as needed and determined by your species condition and soils analysis. We add ample water after application to hold it in place. Since this is a slow release nitrogen fertilizer, we asked ourselves the question, why not apply it all at once. This will enable the seedling to use it whenever they want and need. It's too easy for us to miss the best period of application. Nature and the plant knows this better than any Nurseryman. So in the fall of 1976, we applied 2000 pounds per acre to all the 1-0 stock. Thus it was available in the spring when the seedlings were ready to make their big spurt of growth in May and June. In addition last summer we added 1000 pounds per acre to the rising 2-0's. Our present 2-0 stock looks real good. At the present time we feel in most cases the additional 1000 pounds is unnecessary.

This July we applied 500-700 pounds an acre to the rising 1-0 seedlings. This fall we will apply another 2000 pounds per acre. Overall for a 2-0 conifer seedling we are talking about a total application of about 3000 pounds or a ton and a half per acre.

I wish also to stress that in a ton of Milorganite, you get 75% organic matter. This is exactly what we are looking for. Milorganite comes in a granular form and costs us $160 a ton delivered to Wind River (this computes to 8 cents a pound or about 35 cents per thousand seedlings). This may or may not sound expensive to you. Let me continue on and I'll point out some other properties of this product.

Milorganite is not a simple product. It is probably the most complex fertilizer known. Experiment stations which report better results with Milorganite when compared to other nitrogen sources have been unable to pinpoint the reasons why. That is just how complicated Milorganite is.

Experiment stations have stated the possibility that the heavy metals, (Mercury, Cadmium, etc.) in Milorganite have direct fungicidal properties. It has been well documented that Milorganite fed turf plots have less dollar spot, snow mold and large brown patch disease when compared with other organic, systhetic and water soluble nitrogen materials. We believe it works in a similar manner in the Nursery, as we have very minor disease problems. We also attribute this to our fumigation program.

Other turf management people feel that the active bacterial populations fostered by the use of Milorganite depresses harmful fungi. This theory is based on a given volume of soil being capable of only supporting a given amount of organisms. In other words, if the good guys (bacteria) are active, there is insufficient air, water, food, etc., to support the bad guys (fungi).

Let's get back to cost. Many Nursery and Forest people tell us - Yes it's a good product but too expensive for us. Won't the cost of our seedlings go sky high? When we tell them it only amounts to about .35 - .40 cents a thousand, they feel much better.

The field continues to want larger size seedlings, mainly in the form of larger calipers and larger, more fiberous root systems. If that's what they need, we will give it to them. We are a service unit.

Milorganite has helped us to increase our minimum shipping caliper to 4 millimeters. We can achieve for most species in two growing seasons, just about any seedling height the field desires, dependent upon various cultural practices. Our size for Englemann Spruce and Western red cedar has increased and thus we are now producing 2-0 seedlings instead of the usual 3-0's. We have reduced our transplanting program from a 3½ million production to less than a million seedlings. Field Foresters have observed and reported informally to us of increased field survival, initial elongation and healthier looking trees upon out planting. We strongly believe Milorganite has really helped out in this success. So to us and for these reasons give, the cost is justified. It's too easy to over-simplify this cost factor. We feel whatever the reasons, the over-simplified "cost per unit of nitrogen" formula does not apply to Milorganite. As a matter of fact, unit costs fail to stand up as a very good buyer judgement decision with any fertilizer. You need to weigh the cost against your results and then make a decision whether to use or not.

I like what the Milwaukee Sewerage Commission has to say. I quote from one of their articles. "It can no longer be said that a pound of nitrogen is a pound of nitrogen irrespective of sources."

Some factors for you to consider in selecting a fertilizer in relation to Milorganite are as follows:

- Milorganite is 75% organic matter
- spreader calibration and handling is easy (44 lb. bags)
- has every growth element
- low salt index
- does not burn (very high application and high moisture might cause ammonia burn)
- long lasting
- high analysis - 6% nitrogen
  4.5% phosphoric acid
  .8% potash
  many other trace elements

Fertilizer manufacture at Milwaukee is a part of the plant operation and not an after thought. This isn't an endorsement of Milorganite. We can't do this as you know. My only intent is to tell you that this product gives us excellent results. There are many other fertilizers called 6-2-0 developed from sludge on the market. I caution you to check thoroughly the analysis to see if it truly contains 6% natural organic nitrogen. Also go slow at first and gradually build up applications as needed.

Disadvantages (very few)

1. Slight odor when seedlings are growing.
2. Humidity affects application rates.
3. Need to keep dry - if wet it becomes impossible to handle.

We will continue to monitor and to use Milorganite at Wind River Nursery. We don't know of any product presently on the market that can give us the excellent results in the color, size and quality of seedlings that Milorganite is now producing. Right now I'd say it's our bread and butter. I can't add any more. For us "the proof is in the puddin'". It may be what you are looking for.

MUNICIPAL SLUDGE

I previously mentioned we are working on the possibility of using Municipal Sludge at the Nursery. The University of Washington is putting Seattle Sludge on their conifer Nursery and I am working closely with them. They report that a 4-1 sawdust-sludge composite is giving them tremendous growth (better size and color) over their regular sand-peat mixture at their tree Nursery near Seattle.

I will list some points we have learned about sludge. They are as follows:

1) 100 million tons of sludge is produced annually in the US - only 25% of which is applied to land.

2) It has posed a disposal problem and municipalities are trying to come up with constructive places to put their sludge.

3) Sludge is a cheap but not yet efficient source of nitrogen (Example: to get 200 pounds of nitrogen per acre, you have to add about 50 wet tons of sludge per acre. This is about 14,000 gallons enough to cover the ground with a ½ inch of sludge).

4) <u>Sludge is comparable to commercial fertilizers</u> in terms of crop yield. There's not a shortage of fertilizer, but it takes energy to make. Natural gas is turned into ammonia which contains nitrogen. It's a question of how much can be saved? What can be your benefits by not using commercial fertilizer?

5) <u>Advantages</u> - I will list some that I have learned.

   a. Poorly structured, highly erosive soil can experience sizeable increase in the number of large soil pores after application of sludge at moderates. (Large pores provide oxygen for plant roots.)

   b. Sludge contains many essential plant nutrients and can be used to replace or supplement conventional fertilizer.

   c. Sludge affects physical properties of the soil:

      1. The rate at which water moves in the soil surface is greater for sludge-treated soils than for soils without sludge. This is very important to good plant growth and erosion control.

      2. <u>Improved Structure and Soil Stability</u> - This is important for good root growth and development, plus erosion control.

      3. <u>Organic Matter Content</u> is greater.

6) Disadvantages

   a. Nitrogen wears out - heavy metals like cadmium, zinc, copper, molybdenum, nickel o f some sludges don't.

   b. Water pollution through run off of nitrates. However, nitrates which run off into ground water aren't as noxious as the heavy metals.

c. Aesthetics - odor

d. Diseases

3. Increased browsing on the healthier seedlings - University of Washington has observed this from meadow mice and deer selectively browsing on the seedlings.

7) On environmental questions, sludge is looking very good, but on management questions noted in the problems, the jury is still out. The following management options are available to you to keep the dangerout metals at a relatively low level on sludge-tested land:

a. Maintain soil pH at/or above 6.5 - (We feel we should be between 5.5 and 6.0 for growing conifers at WRN. If soil is allowed to become too acid, the solubility of the heavy metals increases.

b. Grow crops which tend to exclude cadmium from the whole plant or from reproductive tissues.

c. Use sludges which have low cadmium and other heavy metal concentrations.

d. Grow non-edible crops - seedlings

If Federal and State guidelines put the application rates at too low a level, sludge will not be economical to use.

Thus, I feel we need to study sludge to find out the best types and safest way to use on our seedlings and edible crops. If we are knowledgeable about sludge and how to handle, they won't take it away from us.

In summary, if it appears we are going organic at WRN, I would say yes, we are rapidly heading that direction. We need to keep our soils organic content at an acceptable level if we are going to continue to grow the quality and quantity of conifer seedlings the field is asking for. I think that some of the organic farming techniques the Chinese people have employed successfully for over 4,000 years, is part of the answer to restoring the fertility, productivity and organic content of our soils. It certainly will help the waste and pollution problems in our country, and in the future the scarcity and high cost of synthetic fertilizers.

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ALTERNATIVE METHODS FOR EXTRACTING SOUTHERN PINE SEEDS

James P. Barnett[1/]

Abstract.--The mechanics of cone and seed drying and alternative drying techniques are reviewed. Preliminary tests of freeze-drying techniques for extracting southern pine cones and drying seeds indicate that freeze-drying can lower seed moisture contents to less than 2 percent without apparent seed injury. The effects of lower moisture content on seed storability are still under evaluation.

Additional keywords: *Pinus*, seed storage, viability, cone drying, freeze-drying.

Because high kiln temperatures may injure seed, and because the energy required for kiln drying is becoming more expensive, alternative methods of cone opening and seed drying must be found.

MECHANICS OF DRYING CONES AND SEEDS

Pine cones become lignified and hard upon maturity. The hygroscopic scales that enclose the seeds shrink and swell, causing the cone to open. Thus seed dispersal is made possible by cone drying. The rate of drying is proportional to the moisture deficit in the surrounding air, and is influenced greatly by temperature and air movement.

Heat is the primary means of reducing humidity. Heating air raises its saturation point and allows it to absorb moisture more readily. But drying operations require some air movement around the cones. Without air movement, cones or seeds become surrounded by saturated vapor that obstructs heat transfer and limits evaporation. Constant heat and air movement rapidly dry cones and seeds.

BENEFITS OF LOW SEED MOISTURE

One of the main factors influencing seed longevity is seed moisture content. At temperatures at which seeds are normally stored, higher seed moisture causes more rapid decreases in germination capacity (Figure 1). Southern pine seeds should be dried to a moisture content of 10 percent or less before storing (Barnett and McLemore 1970).

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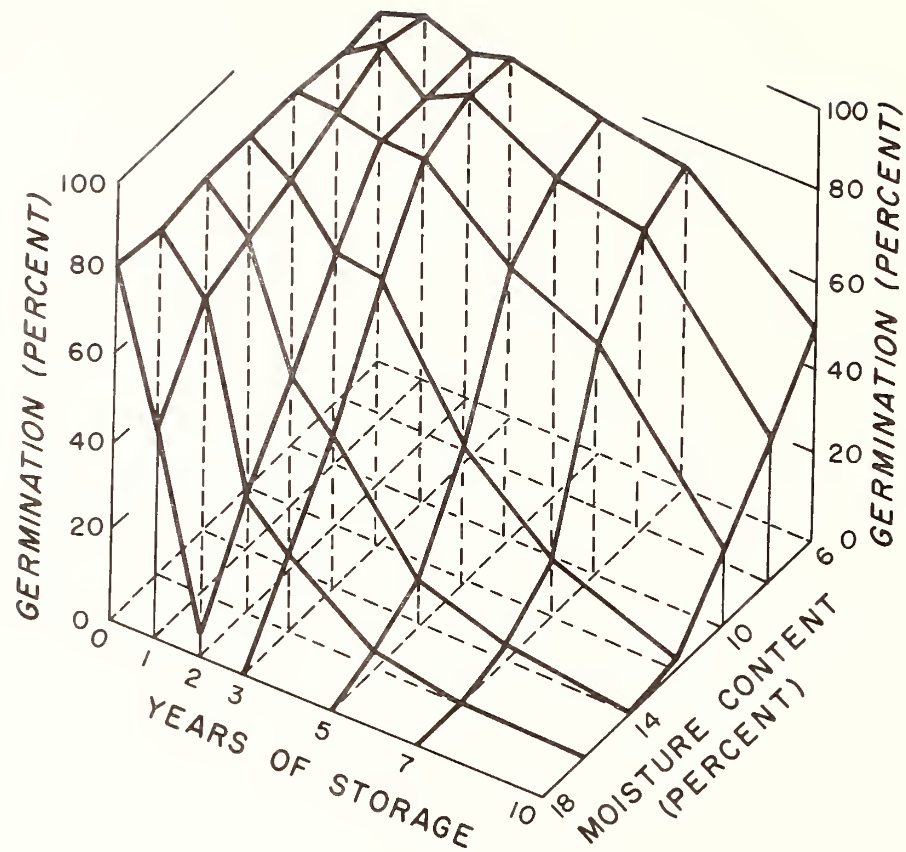

Figure 1.--Germination of longleaf pine seeds as influenced by moisture contents and years of storage at 34° F.

Problems of maintaining seed viability increase with seed moisture content:

Seed moisture above 8-9% -- insects become active and reproduce
Seed moisture above 12-14% --fungi grow on and in seed
Seed moisture above 18-20% -- heating may occur
Seed moisture above 40-60% -- germination occurs (Harrington 1972).

When the seed moisture content is between 5 and 14 percent, each 1-percent increase in seed moisture content halves the life of the seed (Harrington 1959).

Pine seeds are not usually dried below a moisture content of 6 to 8 percent. It is difficult to obtain lower moisture levels with conventional kiln drying techniques. Drying to 1- to 2-percent moisture should maximize the period of viability, but the heat required to dry seeds that much may damage the seeds. Roberts (1972) suggests that decreasing moisture content below 5 or 6 percent may not increase seed storability.

METHODS OF DRYING

Drying is very slow under natural conditions because cones must equilibrate with the relative humidity of the atmosphere around them. Artificial drying is the only way to extract the large quantities of seeds now required in reforestation.

Heated Air

Kiln drying brings about complete cone opening in as short a time as is now possible. Heated air is moved around the cones and seeds. Total drying time depends on initial moisture content, final moisture content desired, rate of airflow, and the temperature of the drying air. Most seeds dry rapidly at first, but dry more slowly as they approach the desired moisture content.

Generally, drying temperatures should not exceed 90° to 110° F. for the southern pines. Higher than conventional drying temperatures can injure seed in the 15- to 30-percent moisture range. Increases in the time that seed remain in the kiln also reduce germination (Rietz 1941).

Solar Drying

Drying in the sun has often been used to open cones in hot, dry regions such as the South or Southwest, where cones are spread on large sheets of canvas. Glass-covered boxes or beds have been used for solar drying in Northern Europe for generations (Baldwin 1942). A solar-heated kiln has recently been designed for use in the South by the Tennessee Valley Authority, but it is limited to small-scale, temporary operations where investment in more complicated equipment is not justified (Barnett and Scanlon 1978).

Dehumidified Air

The use of dehumidified air is a safe method of drying seeds to a low moisture content. Air may be dehumidified by dessicants such as silica gel, calcium chloride, activated alumina, or anhydrous calcium sulfate. Equipment for chemical dehumidification is now commercially available.

Air may also be dehumidified by refrigerating it below its dewpoint, where moisture is condensed. Dehumidified air can then be heated to further increase its moisture-absorbing capacity.

Infrared Drying

Infrared heat has been used to dry seeds (particularly of farm crops) but I know of no application of this technique to cone drying. Radiant heat rays from infrared lamps pass through the air without warming it and are absorbed by the seed. Seeds are heated rapidly, moving the internal moisture to the surface where it evaporates. This is a particularly fast method, since seeds can be dried in a thin layer on a converyor system (Rosberg *et al*.1960).

Vacuum drying

Vacuum drying is especially well adapted to drying seeds to a very low moisture content. Vacuum drying is similar to drying with dehumidified air. In recent years, refrigeration has been combined with vacuum drying in what is termed freeze-drying. Refrigeration is used to condense moisture from the air and lower its vapor pressure. (The term freeze-drying is a misnomer. The material being dried is not necessarily frozen, and can remain at ambient temperatures.) Early results of tests indicate that freeze-drying can improve vegetable seed storability. Moisture content can be lowered to levels that heretofore could not be reached with heat drying without injuring seeds (Woodstock 1975, Woodstock et al. 1976). Freeze-drying has also been tried successfully with spruce seeds (Suber et al. 1973).

Evaluations of freeze-drying southern pine seeds are being conducted because freeze-drying offers the opportunity to improve seed storability by lowering moisture contents well below the minimum of 6 to 8 percent achieved in kilns. The effectiveness of freeze-drying in opening cones is also being tested, since it requires little heat.

PRELIMINARY RESULTS OF FREEZE-DRYING TESTS

Seed

Freeze-drying effectively reduces the moisture content of southern pine seeds to unusually low levels. Early tests resulted in the following moisture contents after 24 hours of freeze-drying (FD):

Species	Moisture content		Germination	
	Initially	After FD	Initially	After FD
	Percent			
Longleaf pine	5.4	0.7	83.4	81.0
Slash pine	12.8	1.8	89.4	91.2

Drying to less than 2 percent seed moisture content had no adverse effect on germination of unstratified seeds that were tested immediately after treatment. The effects of freeze-drying to improve storability by reducing seed moisture contents below levels usually attained by conventional drying methods is still under evaluation. In this and the subsequent evaluations, the seeds remain at ambient temperatures during freeze-drying.

Stratified and unstratified loblolly and slash seeds with widely differing moisture contents were tested, since Woodstock (1975) found that initial moisture contents affected response to freeze-drying. Seed moisture content, germination, and Czabator's (1962) germination values (GV) were determined after oven drying (100° F) and freeze-drying for 24 and 48 hours. Neither method of drying affected germination of unstratified seeds adversely, even though moisture contents were reduced from 6 to 1.2 and 0.7 percent for slash and loblolly pine seeds, respectively (Table 1).

Table 1.--Comparison of oven and freeze-drying methods on seed moisture contents and germination[a]

Species	Drying Method	Length	Unstratified Moisture content	Germ.	Germ. value	Stratified Moisture content	Germ.	Germ. value
		Hours	----Percent---			----Percent---		
Slash	Control	--	6.0	81a	20.7a	43.5	67b	17.2c
	Oven	24	5.0	81a	23.4a	17.9	75a	20.8a
		48	4.0	79a	19.9a	7.6	76a	18.9b
	Freeze-dry	24	1.7	79a	21.1a	11.4	48c	6.3d
		48	1.2	82a	20.2a	7.1	47c	5.3d
Loblolly	Control	--	6.2	90a	19.7a	37.4	90a	36.5a
	Oven	24	5.0	93a	20.4a	12.5	94a	26.8b
		48	3.5	92a	21.6a	4.8	95a	23.6c
	Freeze-dry	24	1.2	92a	19.0a	10.8	79b	16.0d
		48	.7	89a	16.4a	5.4	67c	10.4e

[a] Species means within columns followed by the same letter are not significantly different at the 0.05 level.

Germination of stratified slash and loblolly pine seeds with initial moisture contents of 44 and 37 percent were not adversely affected by oven drying for 48 hours. However, freeze-drying of these moist seeds significantly reduced both rate and completeness of germination. This adverse effect occurred even though the rate of moisture loss was not markedly different between oven and freeze-drying. It is apparent, then, that freeze-drying should not be used to lower seed moisture contents when the initial moisture level is high.

Cones

Shortleaf pine cones were collected and seed were extracted by freeze-drying and conventional kiln techniques. Seed yields per cone averaged 14 for kiln and 16 for freeze-drying extraction (Table 2). Seeds from both treatments were then dried by kiln, oven, and freeze-drying methods. Although the combination of cone and seed freeze-drying resulted in somewhat lower germination and germination values, the differences were not of practical importance. Seed samples are now in storage to evaluate any effects on storability.

These results confirm that dehumidification extraction techniques can produce seed yields as good as conventional kilning without reducing initial seed quality. Further evaluation of such techniques to extract and dry seed to lower than usual moisture levels is yet to be carried out. Reduction in seed vigor may be a more important consequence of drying-related injury than

drop in total germination. But there are no good methods to test vigor and testing germination after storage is still the best way to measure these effects.

Table 2.--Evaluation of effect of alternative methods of shortleaf cone opening and seed drying on seed yield and viability

Method cone opening	Method of seed drying	Seed yield	Seed germination	Germination value
		Seed/cone	Percent	
Kiln	Kiln	---[a]	95	26.3
	Oven	---	94	26.3
	Freeze-dry	---	93	24.3
	Avg.	14	94	25.6
Freeze-dry	Kiln	---	93	24.1
	Oven	---	93	24.1
	Freeze-dry	---	88	19.8
	Avg.	16	92	22.6

[a]Seed drying methods had no effect on seed yield. Although statistical analyses (ANOV $_{.05}$) indicated that freeze-drying resulted in higher seed yields and in lower speed and completeness of germination, these differences are of little practical importance.

APPLICATIONS

Results from these preliminary tests indicate that alternative drying methods can be used to extract seed from pine cones as effectively as conventional kilning. They also show that seed moisture contents can be reduced to levels much lower than those now reached. The lowering of seed moisture offers the possibility of increasing seed longevity, particularly with small lots of unusually high value (such as special genetic material).

The tests do show that freeze-drying seeds with high moisture contents injures the seed. Stratified seed could perhaps be dried to a lower moisture content conventionally, and then freeze-dried to reduce the moisture content further.

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THE QUALITY OF UNEXTRACTED PINE SEED

Robert P. Karrfalt[1]/

Abstract.--Three years of Cone Analysis Service data from the Eastern Tree Seed Laboratory were analyzed to determine the quality of pine seed that is not extracted after one drying of the cones. This unextracted seed was, in general, of poorer quality than extracted seed. However, unextracted seed in some cases represented substantial seed losses. Use of the cone analysis procedure to identify cone lots requiring processing is discussed.

Additional keywords: cone analysis, extraction efficiency, reprocessing, *Pinus sylvestris*, *P. taeda*, *P. elliottii*, *P. virginiana*, *P. palustris*, *P. echinata*.

Unopened or partially opened cones are common at a pine seed extraction plant. It is obvious that some seed is lost in unopened cones, but the value of the unextracted seed is not as obvious. Some seed plant operators have considered partially opened cones worth wetting and reprocessing to increase seed yields per bushel. Van Haverbeke (1977) has shown that wetting and redrying could result in increased yields of full seed from Scotch pine (*Pinus sylvestris*)cones from 18 to 77 percent. In this paper, the quality of unextracted seed is examined in loblolly (*Pinus taeda*), slash (*P. elliottii*), Virginia (*P. virginiana*), longleaf (*P. palustris*), and shortleaf (*P. echinata*) pines. Also, a procedure is described for estimating when a reprocessing of cones would be profitable.

METHODS AND MATERIALS

The cone analysis procedure provides a good method for evaluating the quality of unextracted seed. In this procedure seed are extracted from the cones and tested for quality. Any seed remaining in the cone are removed by cutting the cone apart, scale by scale. The seed removed by cutting (the unextracted seed) are also evaluated for quality. The cones are also subjectively classed as: completely open, 3/4 open, 1/2 open, 1/4 open or not opened at all. The reader is referred to Bramlett, *et. al*. (1978) for a detailed description of the technique.

The Eastern Tree Seed Laboratory has analyzed 3,046, 529, 213, 88, and 272 cones respectively, of loblolly, slash, Virginia, longleaf and shortleaf pines over the three years of 1975, 1976, and 1977. First year ovule abortion, empty seed and potentially sound seed account for 93 to 99 percent of the seed production capacity (table 1). Therefore, this paper will focus primarily on potentially sound seed.

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Table 1.--Summary of combined cone analysis service data from the years 1975, 1976, and 1977.

SPECIES

Characteristics	Loblolly	Slash	Shortleaf	Virginia	Longleaf
Seed Production					
Capacity (# of seeds)	143	181	92	90	147
# of samples	3046	529	272	213	88
1st yr. aborted ovules[a]/	33	40	50	50	51
2nd yr. aborted ovules[a]/	2	4	1	3	3
Insect damage[a]/	1	3	0	1	1
Empty[a]/	15	17	30	21	13
Potentially sound[a]/	49	36	19	26	31

a/ Values are a percentage of seed production capacity.

The quality of extracted and unextracted seed was compared in the following manner. Individual cone data were grouped according to opening classes. For example, all cones opening 3/4 of the way were taken as a group. The average percentage of potentially sound seed for all samples in an opening class was computed for both extracted and unextracted seed. The average for the unextracted seed was subtracted from the average for the extracted seed. These differences are given in Table 2. The same comparisons were also made after grouping samples by clone (Table 3).

RESULTS

Seed Quality

In 39 of 47 comparisons of the percent of potentially sound seed made within cone opening class, the extracted seed appeared to be of higher quality (Table 2). This tendency for extracted seed to be better was also clearly shown in comparisons made within clones (Table 3).

However, the tendency towards higher quality in extracted seed does not necessarily mean that the extracted seed is not worth considering. Table 4 shows the number of loblolly clones that had similar numbers of unextracted potentially sound seed. For 35 of 91 samples that were scored open, there was a minimum of five potentially sound seed left in each cone. Using average figures of 17,000 seeds per pound and 35 cones per bushel, it can be computed that when five potentially sound seeds are lost per cone, there would be a loss of 1 pound of seed per 98 bushels of cones. By most economic analyses, this would be a financial loss of several hundred dollars. The loss would become proportionately larger with more seed left in the cones.

Table 2.--Difference in potentially sound seed percentage between extracted and unextracted seed in loblolly pine within cone opening class.

Species	Cone Opening Score	Extracted-Unextracted (%) 1975	1976	1977
Loblolly	Fully open	+ 1	+ 9**	+ 7**
	3/4 open	+ 7**	+ 8**	+ 8**
	1/2 open	+ 6	+ 7**	+ 4*
	1/4 open	+ 4	+ 6	+21**
Longleaf	Fully open	-----	+11	+11
	3/4 open	-----	+20**	+17*
	1/2 open	-----	-11	+ 1
Slash	Fully open	- 3	+10**	+13**
	3/4 open	+ 2	+ 3	+16**
	1/2 open	- 3	-12*	+14
	1/4 open	- 7	-----	+10
Shortleaf	Fully open	-15*	+ 5	+ 9
	3/4 open	- 8	+ 3	+ 5
	1/2 open	-----	- 1	+ 7
	1/4 open	+21	-----	+ 9
Virginia	Fully open	-----	+11	+33**
	3/4 open	-----	+ 6	+ 6
	1/2 open	-----	+18	+ 4
	1/4 open	-----	+14*	+15

**Statistically significant at .01 level by Student's T-Test.
*Statistically significant at .05 level by Student's T-Test.

Measuring Losses

Table 4 also shows that 13 of 91 cone samples, estimated 3/4 open, are less than one potentially sound seed per cone. Using the same average figures above, it can be determined that over 486 bushels would be discarded before a pound of seed was lost. Clearly, a subjective evaluation of cone opening cannot show the seed plant operator how much seed might still remain in his processed cones. However, the extraction efficiency determination in the cone analysis procedure (Karrfalt and Belcher, 1977) offers a simple, objective method for evaluating how complete an extraction has been.

To apply the technique, select at random, 10 to 20 cones from the lot before opening commences. Place them in a container that will allow them to dry, but remain isolated from other cones and seed, and place in kiln with the rest of the lot of cones. Before tumbling cones, remove the sample and process according to the cone analysis procedure.

Table 3.--The percentage of clonal comparisons in which the percentage of potentially sound seed was greater in extracted seed than it was in unextracted seed.

Year	Species	No. of Comparisons	Percentage of Comparisons
1977	Shortleaf	23	78
1976		3	66
1975		1	100
1977	Virginia	9	89
1976		9	100
1977	Slash	4	75
1976		6	100
1975		50	58
1977	Loblolly	76	82
1976		79	86
1975		126	67

Table 4.--Numbers of loblolly pine cone samples with similar numbers of unextracted potentially sound seed (1976 and 1977 combined).

Number of Potentially Sound Seed Per Cone	1	1-2	2-5	5-10	10+
Cone Opening Score					
Fully opened	0	3	0	1	1
3/4 open	13	22	21	15	20
1/2 open	2	7	14	16	30

Use the following procedure to determine the amount of potentially sound seed:

1. Divide the amount of extracted seed, after cleaning, by the extraction efficiency to determine the original weight of seed in the cone lot.

2. Subtract, the weight extracted, from the original weight to determine the weight of potentially sound seed remaining.

As an example, consider a cone lot which yielded 100 pounds of cleaned seed following extraction and had an extraction efficiency of 95 percent. The original weight of potentially sound seed would be 105 pounds (100÷.95). Subtracting the 100 pounds of cleaned seed shows that 5 pounds of potentially sound seed would still remain in the lot of cones.

We can carry our example one step farther and assume a value of $60 per pound for this seed. This would mean that the total value of the unextracted seed is $300. With a cone lot containing 100 bushels we would be able to spend up to $3.00 per bushel to reprocess the cones and recover the extra 5 pounds of seed. In reality, extraction and processing costs would need to be somewhat less than $3.00 per bushel because a complete extraction of the seed would probably not be realized.

Extraction Efficiency

Bramlett *et al.* (1978) described two methods of estimating extraction efficiency, procedure A&B. The B procedure followed by the Eastern Tree Seed Laboratory is favored because procedure A tends to underestimate the percentage of the potentially sound seed actually extracted. Procedure A would, therefore, tend to indicate reprocessing more often than procedure B, but to no benefit. In 96 percent of all clonal comparisons, over all species in the three years considered, procedure A did not measure the true percentage of potentially sound seed extracted. Procedure A was found at times to be inaccurate by as much as 10 to 20 percent.

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SELECTIVE HERBICIDES REDUCE WEEDING COSTS

IN TWO MISSISSIPPI NURSERIES

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Abstract.--In tests conducted from 1974 to 1977, the preemergence herbicides, Treflan, Eptam, Dymid, and Destun[1/] reduced weeds and weeding costs in seedling beds of loblolly, slash, and shortleaf pine. Velpar and Roundup controlled weeds along riser lines.

Additional keywords: Nursery, weed control, seedling tolerance, cost comparisons, *Pinus taeda*, *P. elliottii*, *P. echinata*.

Introduction

Before 1974, weed control in pine seedling beds at the W. W. Ashe nursery in Brooklyn, Mississippi, and the Mississippi Forestry Commission nursery at Winona was dependent upon two soil fumigants, methyl bromide and Vorlex. Fumigation was expensive, and the control of annual weeds was often inconsistent. Extensive hand-weeding was needed throughout the growing season.

Riser line areas, where fumigation is impractical, were a continual problem. These areas were kept clean by hoeing or were sprayed with mineral spirits, which was effective only on small weeds.

Due to the rising costs of fumigation, it became evident to the nurserymen that selective herbicides were needed to provide more consistent weed control in both seedling beds and riser lines.

From 1974 to 1977 studies were conducted at these nurseries to evaluate several preemergence herbicides for weed control in seedling beds and their effects on production of loblolly (*Pinus taeda* L.), slash (*Pinus elliottii* Engelm. var. *elliottii*), and shortleaf (*Pinus echinata* Mill.) pine seedlings. Two postemergence herbicides were tested for weed control along riser lines. Highlights of the results on weed control, seedling tolerance, and comparative costs are covered in this report.

1/ Throughout this article, mention of trade names is for information only and does not constitute a recommendation by the U.S. Dep. Agric. Before any chemical is applied, the user should make certain that it is registered for the purpose intended.

Materials and Methods

Seedling Beds--Preemergence Herbicides

Preemergence treatment plots ranged in size from 6 X 35 ft. to 6 X 50 ft. with 6-9 replications per treatment (including one control), depending on length of beds and size of study area used in each nursery. Plots were arranged in a randomized complete block design.

In 1974 the following preemergence treatments were applied: trifluralin (Treflan) at 1 and 2 lbs. a.i./A. (active ingredient per acre), diphenamid (Dymid) at 4 and 8 lbs. a.i./A., and perfluidone (Destun) at 1.25 and 2.50 lbs. a.i./A. Treatments were tested on loblolly seedbeds at both locations and also slash seedbeds at the W. W. Ashe nursery.

The 1975 treatments consisted of perfluidone 50 WP at 1 and 2 lbs. a.i./A., perfluidone 4S at 1.5 lbs. a.i./A., and EPTC (Eptam) at 3 lbs. a.i./A. Species treated were loblolly and slash at both locations and shortleaf at the W. W. Ashe nursery.

The 1976 treatments were trifluralin at 1 lb. a.i./A., EPTC at 3 lbs. a.i./A., perfluidone 50 WP at 1 and 1.5 lbs. a.i./A., combinations of trifluraline (1 lb. a.i./A.) with perfluidone 50 WP (1 and 1.5 lbs. a.i./A.) and EPTC (3 lbs. a.i./A.) with perfluidone 50 WP (1 and 1.5 lbs. a.i./A). Species treated were the same as in 1975.

The 1977 study was conducted only at the W. W. Ashe nursery on loblolly and slash seedbeds. Treatments consisted of perfluidone 50 WP at 1.5 lbs. a.i./A., bifenox (Modown) at 3 lbs. a.i./A., prometryne (Caparol) at 1 lb. a.i./A. and a combination of napropamide (Devrinol) at 1 lb. a.i./A. with bifenox at 3 lbs. a.i./A. (tank mix). Metolachlor (Dual) was used at 1.5 lbs. and 3 lbs. a.i./A.

The Treflan, Eptam, and Dymid treatments were applied before seeding and incorporated with a nursery-bedshaper. All other preemergence treatments were applied after seeding and mulching. Seedbeds were irrigated with 3/4 to 1 inch of water immediately after spraying.

Each year at the time of the first weeding, broadleaf weed and grass counts were made in two randomly selected 1X4-ft. subplots within each treatment replication. Weeds were identified by species and data analyzed to determine which species were being controlled by herbicides. Except in 1974, weeding times were also recorded. In 1975, the time required for two people to handweed two randomly selected 1X4-ft. subplots within each treatment replication was recorded at first weeding. In 1976 and 1977 weeding times were recorded for the entire plot in each treatment replication throughout the growing season.

Riser Lines--Postemergence Herbicides

Postemergence tests for control of established weeds in riser lines were conducted at the W. W. Ashe nursery in 1975 and at the Winona nursery in 1976.

The 1975 treatments were glyphosate (Roundup) at 1 and 2 lbs. a.i./A. and hexazinone (Velpar) at 0.75 and 1.5 lbs. a.i./A. Two lines of 3 X 1,000 ft. were each divided into two equal blocks. Treatment plots (including a control) of 3 X 50 ft. were assigned within each block in a randomized complete block design with 8 replications per treatment.

In 1976, Velpar at 1.5 and 3 lbs. a.i./A. was tested at Winona. Three lines 2 X 1,000 ft. each were divided into four equal blocks. Treatment plots (including one control) of 2 X 80 ft. were randomly assigned within each block in a randomized complete block design with 12 replications per treatment. One complete line and 240 ft. of each of the other two had been hoed 24 hours before herbicide treatment. These areas were free of all weeds except purple nutsedge (*Cyperus rotundus*) which was already showing regrowth.

Herbicides were applied with a hand-spray nozzle attached to a sprayer mounted on the rear of a tractor. Equipment was calibrated to deliver approximately 40 gallons of mixture per acre. A man walked behind the tractor and applied chemical evenly over the entire plot.

Results and Discussion

Seedling Beds--Comparative Costs

In 1975, soil fumigants were not used in study areas before planting. Weeding times recorded on first weeding date at the W. W. Ashe nursery showed all preemergence herbicide treatments had greatly reduced weeding times. Relative cost figures prepared from data showed a savings of at least $1,000 per acre compared to control plot data (Table 1). Similar results were obtained at Winona.

In 1976, weeding cost was reduced by approximately $250 to $470 per acre at Winona even though Telone C was applied at 30 gal. per acre prior to planting (Table 2). Similar results were obtained at W. W. Ashe nursery where methyl bromide was used as a soil fumigant.

Weed Control--Sedge and Grass

Weed control was most evident in sedge and grass control. The most predominant species at both locations were purple nutsedge (*Cyperus rotundus*), *Cyperus compressus*, watersedge (*Cyperus erythrorhizos*), crabgrass (*Digitaria sanguinalis*), broadleaf signalgrass (*Brachiaria platyphylla*), and goosegrass (*Eleusine indica*). Prairie cupgrass (*Eriochloa contracta*) was the dominant

Table 2.--Winona nursery. Cost comparison--total 1976 weeding season.

Treatment	Rate lb. a.i./A.	Time Hr./A.	Labor Cost/A.	Fumigant	Chem. Cost/A.	Total cost Dollars/A.
Eptam + Destun 50 WP	3.0 + 1.5	1/ 24	2/ 144	3/ 180	4/ 25	349
Eptam + Destun 50 WP	3.0 + 1.0	26	156	180	20	356
Treflan + Destun 50 WP	1.0 + 1.5	27	162	180	24	365
Treflan + Destun 50 WP	1.0 + 1.0	36	216	180	19	415
Eptam	3.0	43	258	180	10	448
Treflan	1.0	44	264	180	9	453
Control	None	107	642	180	None	822

1/ Determined from average time required for two people to handweed 1 $ft.^2$ of bed surface per treatment plot.

2/ Labor at $6.00/hr.

3/ Telone C-30 gal/A. @ $6.00/gal.

4/ Eptam-$19.00/gal; Destun-$5.00/lb; Treflan-$34.00/gal.

Table 1.--Cost comparisons at first weeding (June 24, 1975) in the W. W. Ashe nursery.

Treatment	Rate lb. a.i./A.	Weeding time Hr./A.	Total cost dollars/A.
Destun 4S	1.5	1/ 21.4	2/ 182.00
Eptam	3.0	22.4	188.00
Destun 50 WP	2.0	23.5	208.00
Destun 50 WP	1.0	23.6	199.00
Control	None	158.9	1,271.00

1/ Determined from average time required for two people to handweed 1 $ft.^2$ of bed surface per treatment plot.

2/ Includes labor-@$8.00 per hr.; Destun 50 WP--$5.00/lb., Eptam-$19.00/gal.; Destun 4S-$28.00/gal.

species at Winona in 1976. Analysis of data taken on first weeding dates each year and weeding times recorded in 1975 and 1976 showed that all pre-emergence herbicide treatments had significantly reduced the total number of grasses per ft.^{2} and total weeding times.

In areas where *Cyperus* sp. (particularly *C. rotundus*) were predominant, treatments with Destun at 1.5, 2.0 or 2.5 lb. a.i./A. gave excellent control.

In 1976 at Winona, treatments of Treflan or Eptam combined with Destun were the most effective.

In 1977, at the W. W. Ashe nursery weed populations were too low in control plots to make valid comparisons.

Broadleaf Weeds

Broadleaf weeds were not a serious problem at either location during the 4 years. Populations in control plots were usually not heavy enough for consistent results. The most predominant broadleaf weeds observed in check plots at both locations were carpetweed (*Mollugo verticillata*) and yerba-de-tago (*Eclipta alba*). Eight other species were observed but were not as abundant.

In 1974, control was obtained in the loblolly treatment area at the W. W. Ashe nursery with Treflan at 1 and 2 lbs. a.i./A. and Dymid at 8 lbs. a.i./A. In 1975, Destun 50 WP at 2 lbs. a.i./A., Destun 4S at 1.5 lbs. a.i./A. and Eptam at 3 lbs. a.i./A. reduced total number of broadleaf weeds per ft.^{2} in both loblolly and slash treatment areas at Winona. Combined treatments of Treflan or Eptam with Destun at 1.0 and 1.5 lbs. a.i./A. were the most effective in 1976.

Seedling Tolerance

In 1974, Destun at 2.5 lbs. a.i./A. caused top curl in germinating loblolly pine seedlings at both locations. The symptoms disappeared within 6 weeks after germination and did not affect seedling production.

In 1975, germination of shortleaf pine seed was slightly reduced by Destun at 1.5 and 2.0 lbs. a.i./A. rates. The number of plantable seedlings was not reduced.

In 1976 at the W. W. Ashe nursery, the average height of loblolly and shortleaf pine seedlings in plots treated with a combination of Treflan at 1 lb. a.i./A. and Destun at 1.5 lbs. a.i./A. was 1 inch shorter than control plot seedlings. Also the number of plantable shortleaf seedlings was reduced by 10 per ft.^{2}.

In 1977, the number of plantable loblolly seedlings was slightly reduced (3 per ft.^{2}) by Destun at 1.5 lbs. a.i./A. when hydromulch was used as a seed covering. This combination may have been a contributing factor since seedling production had not been reduced in previous tests with Destun at 1.5 lbs. a.i./A. where sawdust or pine bark mulch was used. Dual at 3 lbs. a.i./A. reduced the number of plantable loblolly and slash seedlings by 12 and 14 per ft.^{2} respectively, and by 6 and 5 per ft.^{2} at the 1.5 lb. a.i./A. rate. Both rates had reduced seed germination. Seedling production was not affected by Modown, Caparol, and the combined treatment of Devrinol plus Modown.

Riser Lines--Weed Control

In 1975, at the W. W. Ashe nursery, Roundup at 2 lbs. a.i./A. satisfactorily controlled established weeds for approximately 6 weeks following application. Velpar at 0.75 and 1.50 lbs. a.i./A. controlled all weeds except purple nutsedge. Control with Roundup at 1 lb. a.i./A. was not satisfactory.

In 1976 at Winona, Velpar provided 100% weed control at 1.5 and 3 lbs. a.i./A. in hoed areas and at 3 lbs. a.i./A. in non-hoed areas. Approximately 90% control was obtained with the 1.5 lbs. a.i./A. rate in the non-hoed areas. Purple nutsedge and goosegrass began to germinate 10 weeks following treatment.

Conclusions

Savings in weeding cost in pine seedling beds can be expected with selective preemergence herbicides even when soil fumigants are used. Total savings will vary depending on predominant weed species and herbicides used. For most annual weeds adequate control can be obtained with a preemergence application of either Treflan (1 lb. a.i./A.), Eptam (3 lbs. a.i./A.), Dymid (8 lbs. a.i./A.) or Destun (1.5 lbs. a.i./A.). In some areas a combined treatment may be needed. The combined treatments of Treflan or Eptam with Destun were the most effective at Winona in 1976.

In areas where Cyperus sp. were dominant, Destun was the most effective herbicide tested. However, additional tests should be conducted in shortleaf pine seed beds and in loblolly seed beds where hydromulch is used. Combination of Destun with other herbicides should be further tested.

Preemergence applications of Modown (3 lbs. a.i./A.) Caparol (1 lb. a.i./A.) and a tank mix of Modown (3 lbs. a.i./A.) with Devrinol (1 lb. a.i./A.) did not affect loblolly and slash pine seedling production at the W. W. Ashe nursery in 1977.

Annual weeds can be controlled along riser lines with Velpar or Roundup. A preemergence treatment with Velpar at 1.5 lb. a.i./A. was the most effective. For established purple nutsedge a postemergence application of 3 lbs. a.i./A. will provide total season control. More than one application of Roundup at 2 lbs. a.i./A. will be needed for satisfactory control.

INTEGRATED WEED MANAGEMENT IN SOUTHERN FOREST NURSERIES

David B. South[1/]

Integrated weed management provides an optimum level of weed control by utilizing many types of control tactics and results in economic or optimal production with minimum deleterious effects on the environment. However, many nurserymen rely on only a few weed control tactics. Some nurserymen rely heavily on one herbicide and might apply it twice a week throughout the growing season. This practice can lead to a buildup of resistant weeds. Some nurserymen fumigate yearly for weed control with methyl bromide which is not only expensive but also can be dangerous to humans and can have detrimental effects on beneficial soil organisms. A few nurserymen have eliminated their need of fumigation for weed control, reduced their herbicide usage, and reduced their weed population by integrating several types of weed control practices.

PAST PRACTICES OF INTEGRATED WEED CONTROL

Prior to 1947, southern pine nurseries were weeded almost entirely by hand or in combination with mechanical cultivation (Wakeley 1954). Weed populations were high and an acre of seedlings often required from 200 to 800 man-hours to handweed (McKellar 1936). Wakeley (1935) reported that several methods including sanitation practices, cultivation, cultural practices and biological control measures could be used by the nurserymen to reduce weed populations. To avoid spreading nutsedge (*Cyperus rotundus* L. and *C. esculentus* L.), use of spiked-toothed or spring toothed harrows was not recommended since the tubers tended to cling to the tines. Toothed harrows were recommended for controlling bermudagrass (*Cynodon dactylon* (L.) Pers.) since the rhizomes would be brought to the surface and exposed to freezing temperatures over the winter which resulted in reduced survival. By sowing late, germinating weeds could be controlled by working the soil before sowing. Weed seed population for the following season could be reduced by preventing the weeds on areas adjacent to the nursery from going to seed. Introduction of weeds from outside the nursery was prevented by not using soil admendments contaminated with weed seed. The use of heavy cover crops was recommended to shade out the weeds and reduce their population. Even biological control of nutsedge was recommended. Geese were used to eat the leaves of nutsedge and hogs would eat the tubers. McKellar (1936) reported that serious perennial weeds were controlled by digging up the soil, and sifting it to remove the vegetative parts.

Millions of southern pine seedlings were mechanically cultivated in the nursery with more or less satisfactory results (Wakeley 1954). Because of narrow row spacing, seedlings were often destroyed by cultivation and incidence of injury and disease was increased. For this reason, mechanical cultivation of southern pine seedbeds is no longer practiced. Mechanical cultivation becomes more feasible when row spacing is wider, such as with hardwoods. For the past twenty years, Howard Stanley (1970) has mechanically cultivated hardwoods grown in 36-inch rows. Several types of seedbed and alleyway cultivators are available (Lowman and McLaren 1976).

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Peanut diggers have been used in forest nurseries to control nutsedge (Cossitt 1957). The machine picked up tubers and deposited them on the soil surface. The operation was conducted in hot dry weather and after 4 days of drying, the nuts were killed.

Another method which can help in controlling nutsedge and bermudagrass involves working the soil up for winter. After the summer cover crop is turned under, a disk harrow is used to level the soil surface. The area is then plowed on the contour with a middle buster plow which throws up a high ridge called a "listed bed". In severe winter, soil infested with tubers or rhizomes will freeze in at least the upper third of the listed bed, thus killing the weeds. Over the winter, the beds will weather down and expose more tubers and rhizomes to the freezing weather. This method was used to prevent soil erosion and help reduce nutsedge at the Hauss Nursery in Alabama.[2/]

INCREASING THE POPULATION OF HERBICIDE RESISTANT WEEDS

Today, however, many nurserymen tend to rely heavily on the use of chemicals and less on sanitation and cultural practices. By using the same chemicals year after year in the seedbeds these nurserymen discover that the population of hard-to-kill weeds increases each year. The reason for this is a simple matter of genetics. The nurserymen are selecting the resistant weeds by allowing them to go to seed. In addition, by not using a herbicide for the cover crop to which these weeds are susceptible, the population is allowed to increase each year.

In 1947, Floyd Cossitt (1947) stated that, "...the population (of weeds resistant to mineral spirits) can be reduced greatly by persistent removal before seed is formed." Many nurserymen paid little attention to this advice and 21 years later Mason Carter (1968) was saying, "In many cases, the use of mineral spirits over many years has led to an increase in weeds which are resistent to it." At one nursery, a weed resistant to mineral spirits, button-snakeroot (*Eryngium protratum* Nutt.), had increased to such a population that an acre of seedlings required 600 to 900 man-hours of handweeding annually (Shoulders *et al*. 1965). Other instances of weeds acquiring resistance have been reported. At the Mt. Sopris Tree Nursery in Colorado, common purslane (*Portulaca oleracea* L.) has apparently developed resistance to herbicides (Landis 1976). At one nursery in Washington where simazine or atrazine had been used once or twice annually for ten years, common groundsel (*Senecio vulgaris* L.) built up resistance (Ryan 1970). Even when simazine was applied at 16 lb ai/A, the resistant groundsel was unaffected. Normally, common groundsel is susceptible and 1 lb ai/A of simazine can provide effective control.

The buildup of resistant weeds could have been prevented by integrating two practices into the nurseries' weed control program. First, by persistent removal of resistant weeds before seed production, their population would decrease. And second, by rotating to a different herbicide (one from a different herbicide family) when growing cover crops, resistant weed populations would be further suppressed. Examples of herbicides which can be utilized in cover crops are presented in Tables 1 and 2.

[2/] Personal communication, Carl A. Muller, Hammermill Paper Company, Selma, Alabama.

Table 1
EXAMPLE OF A WEED CONTROL PROGRAM FOR GRASSES AND BROADLEAVES IN PINE NURSERIES[a/]

Time of Application	Herbicide Trade Name[b/]	Comments
April	Modown + Devrinol[c/]	Apply to seeded beds before or after mulching. If mulch is likely to be washed off bed, application should be made before mulching. Apply herbicides before weed seed germination (within 48 hours after seeding is possible). Make sure herbicides are applied to riserlines before weeds germinate.
	Velpar	Apply to fencerows and other non-crop areas where weeds may grow to produce seed. Since this product is persistant in the soil, do not use on areas to be planted to crops.
May	Modown	Apply 4-6 weeks after seeding. Best results are obtained when applied before weeds appear. If weeds are not present, irrigate after application. If small weeds are present, the EC formulation will provide more contact activity than the WP formulation. Contact activity will be enhanced if irrigation is not applied until 48 hours after treatment. The use of a surfactant may slightly improve contact activity. Weed control will be decreased if weeds are past the 1-2 leaf stage. Handweed to prevent resistant weeds from going to seed.
June	Modown	Apply 8-12 weeks after seeding in same manner as above if needed. Handweed resistant weed species.
July-November		Keep all weeds around nursery from going to seed.
December-March		Lift pine seedlings.
May		For soybean cover crop
	Basalin or Prowl or Tolban or Treflan + Vernam tank mix	Apply preplant incorporated.
		OR
	Lasso + Sencor	Apply a preemergence herbicide after planting soybeans.
	Basagran or Tenoran + surfactant	Apply postemergence to small weeds if needed.
		For corn cover crop
	Sutan+ or Eradicane	Apply preplant incorporated.
		OR
	AAtrex or Atrazine or Princep or Lasso	Apply a preemergence herbicide after planting corn.
	AAtrex or Atrazine	Apply postemergence if needed.
		For grain sorghum cover crop
	Milogard	Apply preemergence.
		OR
	AAtrex or Atrazine	Apply postemergence.

[a/] This does not constitute recommendations by Auburn University. This is only an example of a theoretical weed control program. Since soil conditions and weed populations vary from nursery to nursery, specific recommendations should be made only to fit each nursery's situation.

[b/] Read the label and use recommended rates.

[c/] We do not recommend the use of Devrinol on soils containing less than 1% organic matter. On soils less than 1% organic matter or in states where Devrinol is not registered, Enide sometimes may be helpful in controlling some grasses.

Table 2
EXAMPLE OF A WEED CONTROL PROGRAM FOR A LARGE INFESTATION OF NUTSEDGE IN PINE NURSERIES[a]

Time of Application	Chemical Trade Name[b]	Comments
Fall	methyl bromide	Best results are obtained when soil temperature is above 60°F, at the 4-inch level and soil is moist, fine and loose. Moisture content of the tubers must be high for good control. Continuous tarping reduces the possibility of leaving some soil untreated.
March	EPTAM 7E	Apply and incorporate at least 14 days prior to seeding.
April		Plant pine seed and apply appropriate preemergence herbicides to control grasses and broadleaves.
May-September	Roundup	Apply as a spot spray to nutsedge on riserlines, in allyways and in fallow fields. Nutsedge should be sprayed when it's large, healthy, rapidly growing, and just before it goes to seed. Care should be used when treating nutsedge plants among the pines since seedlings will die if the spray contacts their foliage. The use of shields can help reduce seedling injury. Also, well placed dribble applications may be less harmful to the pines than spray applications.
December-March		Lift seedlings.
April-May	Roundup	After lifting seedlings, leave the area undisturbed and let the nutsedge tubers germinate. Encourage nutsedge growth by irrigation if necessary. When the nutsedge is large, rapidly growing, and just prior to putting on seed, spray with Roundup. Do not cultivate the area until 14 days after treatment.
May		For soybean cover crop
	Vernam	Incorporate thoroughly into the soil.
	Basagran	Apply as a postemergence treatment when yellow nutsedge is young and rapidly growing. (Will not control purple nutsedge.)
		For corn cover crop
	Eradicane or Dual	Incorporated thoroughly into the soil. Preemergence.
	AAtrex or Atrazine + emulsifiable oil	Apply after the crop and yellow nutsedge have emerged, but before the nutsedge plants reach a height of 3 inches.
		For sorghum or sorghum-sudan cover crop
	AAtrex or Atrazine + emulsifiable oil	Apply after the crop and weeds have emerged, but before the weeds reach aheight of 3 inches.

[a] This does not constitute recommendations by Auburn University. This is only an example of a theoretical weed control program. Since soil conditions and weed populations vary from nursery to nursery, specific recommendations should be made only to fit each nursery's situation.

[b] Read the label and use recommended rates.

USING LESS FUMIGATION

At many nurseries, herbicides can provide weed control equal to or better than that obtained with methyl bromide fumigation. If control of annual grasses and broadleaves is the major objective, herbicides are often a better choice than methyl bromide fumigation because herbicide applications cost about one-tenth as much, are easier and safer to apply, and provide at least as effective weed control.

For methyl bromide to provide effective weed control, exacting soil conditions must be met. The soil should be fine and loose with no lumps or clods. Soil temperature at the 4 inch depth should be above 60°F. Soil moisture should be moderate (but not too wet), since moisture content of weed seeds must be high for good control.

When fumigation of the nursery is done by a contractor, special problems may arise. Often a contractor is available at the nursery for only a few days and has to fumigate the nursery under less than ideal conditions. We know of one case where the contractor arrived at the nursery and began fumigating, but had to stop because of a snow storm. If fumigation is done in the spring, any delay by the contractor can delay planting.

It should be remembered that methyl bromide has no residual activity. Weeds will grow vigorously on fumigated soil if the area is contaminated by weed seed in straw mulches, nonfumigated soil, or by wind-carried seed.

From 1972 to 1977, ten studies at seven nurseries were conducted to compare weed control obtained from methyl bromide fumigation with that obtained from herbicides. All but two of the tests indicated that herbicides alone provided better weed control than fumigation (Figure 1).

At most nurseries, the cost of fumigation is unjustified for controlling annual grasses and broadleaves. However, methyl bromide can be justified when controlling high populations of nutsedge or when pathogens are a problem.

USING LESS HERBICIDE

There are several applicators available which allow the nurserymen to make more efficient use of herbicides. One such device is known as a rope-wick applicator which is primarily used for the application of glyphosate (Roundup) (Dale 1978). Since glyphosate is expensive but effective against perennial weeds, use of this applicator might be most appropriate at nurseries with a nutsedge problem. The principle of the applicator involves a loose woven nylon wick which conveys the concentrated herbicide to weeds that physically contact the wick as the tractor moves through the field (Figure 2). A conventional broadcast application of glyphosate would waste herbicide that was sprayed on bare ground. Although a higher concentration of herbicide is used with the rope-wick applicator (approximately 50% Roundup with 50% water), the only herbicide used is that which is directly rubbed off onto the plant. This applicator not only can be used in non-cropland situations, but also can be used early in the growing season when the nutsedge plants are much taller than the pine seedlings. However, if the rope comes in contact with the seedlings or drops of herbicide fall unto seedlings, death of seedlings will result.

FIGURE 1. . WEED CONTROL FROM FUMIGATION AND HERBICIDES AT SEVERAL SOUTHERN FOREST NURSERIES

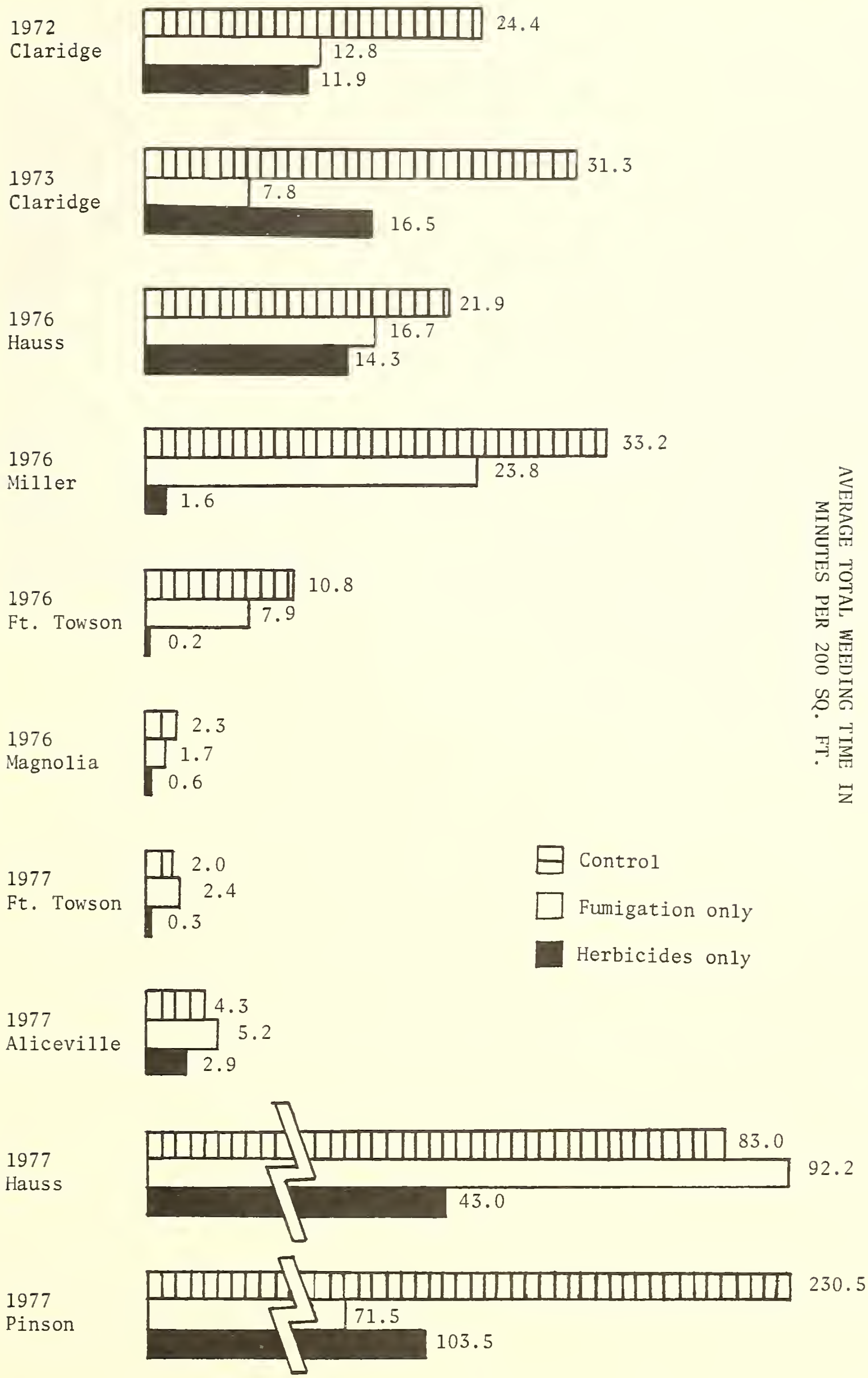

Figure 2.-- Rope-wick applicator

Another applicator which might reduce herbicide usage is one which involves Ultra Low Volume Application (ULVA). The ULVA device runs off of batteries which spin a disc that produces uniform herbicide droplets in the range of 250 microns in diameter (McGarvey 1978). By producing a uniform droplet size, the company claims better plant coverage is obtained and lower herbicide dosages are required to obtain adequate weed control. This applicator might be most appropriate for use around seed orchard trees and for use along fencerows, etc.

One applicator which should replace the putty knife for nutsedge control is the pump spray bottle (Figure 3). The putty knife only removes the top of the nutsedge plant and doesn't get to the "root" of the problem. A pump spray bottle (such as that used for window cleaners or household cleaners) can be used to directly apply a glyphosate solution (approximately 1 part Roundup to 10 parts water) to nutsedge plants. The herbicide will translocate down and kill the tubers and is much more efficient in controlling nutsedge than just removing the tops.

Figure 3.--A spot application of glyphosphate on nutsedge using a "pump spray bottle"

INTEGRATED WEED MANAGEMENT PROGRAM

An integrated weed management program must be adapted to each nursery's particular situation. Weed species dictate which practices should be emphasized and the practicality of the practice will determine to what extent it is utilized. When designing a weed control program, the following practices should be considered.

I. <u>Sanitation</u>

A. Prevent the introduction of weeds and weed seed into the nursery
   1. Use weed-free mulches
   2. Use cover crop seed which are free of weed seed (use certified seed)
   3. When irrigation source is a lake, pond, or river, use screens to filter out weed seed
   4. Do not bring in combines or other machinery which are contaminated with weed seed
   5. Do not use soil amendments which are contaminated with weed seed (such as leaves from lawns which contain weed seed (i.e., bermudagrass)
   6. Use windbreaks to reduce the introduction of wind borne seed

B. Prevent weeds from going to seed
   1. in seedbeds
   2. on riserlines
   3. on fencerows
   4. in cover crops
   5. in drainage ways and culverts
   6. in all areas adjacent to the nursery

C. Limit the spread of weeds which reproduce vegetatively
   1. Keep all machinery clean of vegetative parts
   2. Cultivate weed-free areas before entering infected areas

C. Cover crops
   1. Annual grasses
      a. butylate (Sutan+) - also controls bermudagrass from seed
      b. EPTC (Eradicane) - also suppresses rhizome bermudagrass
      c. cyanazine (Bladex)
      d. alachlor (Lasso)
      e. metolachlor (Dual)
      f. fluchloralin (Basalin)
      g. trifluralin (Treflan)
      h. profluralin (Tolban)
      i. vernolate (Vernam)
      j. propazine (Milogard)
   2. Broadleaves
      a. atrazine (AAtrex)

II. Mechanical Weed Control

A. Cultivation
   1. of cover crops
   2. of hardwoods grown in wide rows
   3. on noncrop areas
   4. of alleyway

B. Separation of nutsedge tubers from the soil
   1. Peanut diggers
   2. Modified rock picker
   3. Soil screens

III. Chemical Weed Control

A. Pines
   1. Annual grasses
      a. diclofop (Hoelon)*
      b. napropamide (Devrinol)
      c. diphenamid (Enide)
      d. oxyfluorfen (Goal)*
      e. mineral spirits (Amoco Weed Killer)
   2. Broadleaves
      a. bifenox (Modown)
      b. oxyfluorfen (Goal)*
      c. mineral spirits (Amoco Weed Killer)
   3. Nutsedge
      a. methyl bromide
      b. EPTC (Eptam)

B. Hardwoods
   1. Grasses
      a. trifluralin (Treflan)
      b. napropamide (Devrinol)*
   2. Broadleaves
      a. oxadiazon (Chipco Ronstar)
   3. Nutsedge
      a. methyl bromide

b. propazine (Milogard)
c. simazine (Princep)
d. cyanazine (Bladex)

3. Nutsedge
   a. butylate (Sutan+)
   b. EPTC (Eradicane)
   c. vernolate (Vernam)
   d. alachlor (Lasso) - erratic control of yellow nutsedge only
   e. metolachlor (Dual) - yellow nutsedge only

D. Noncropland
   1. All weeds
      a. glyphosate (Roundup)
      b. hexazinone (Velpar)
      c. diuron (Karmex)
      d. simazine (Princep)

IV. Biological Weed Control

A. Handweeding
B. Geese
C. Hogs
D. Competition from cover crops

* Not registered at time of printing

SUMMARY

Handweeding constitutes at least 10 percent of the total cost of seedling production at approximately half of the forest nurseries in the United States (Abbott and Fitch 1977). Costs for fumigation and herbicides would run the total cost of weed control even higher at these nurseries. By utilizing an integrated weed control program, need for fumigation for weed control can be eliminated and the total cost for weed control can be reduced to only 22¢ per thousand seedlings ($.00 per M for fumigation, $.08 per M for handweeding, $.08 per M for herbicides and $.06 per M for labor associated with herbicide application).3/

PESTICIDE PRECAUTIONARY STATEMENT

All uses of pesticides must be registered by appropriate State and Federal agencies before they can be recommended. Since Federal registrations are constantly changing and some states also have pesticide restrictions, check with the Forest Nursery Weed Control Cooperative at Auburn University or with the Pesticide Specialist for U.S.F.S. State and Private Forestry at Atlanta, Georgia for up-to-date information. Caution: Pesticides can be injurious to human, domestic animals, desirable plants, and fish or other wildlife - if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

3/ Personal communication, Carl A Muller, Hammermill Paper Company, Selma, Alabama.

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FUSIFORM RUST CONTROL WITH SYSTEMIC FUNGICIDES

John Mexal, G. A. Snow, and William G. Morris[1/]

Abstract. Effective control of fusiform rust in southern nurseries is often incomplete with ferbam. Two systemic fungicides offer promise of improving the level of control. Benodanil (four applications) was tested two years in the nursery and shown to be as effective as over 30 applications of ferbam. Bayleton treatment of seed was found to afford protection in a laboratory trial. The fungicide did not impact seed germination, but did significantly reduce rust infections following germination. Future research needs are discussed in light of the findings.

INTRODUCTION

Fusiform rust caused by Cronartium quercuum (Berk.) Miyabe ex Shirai f. sp. fusiforme (Burdsall and Snow, 1977) is the most serious threat to pine seedling production in southern nurseries. Current control methods consist of frequent applications of the contact fungicide, ferbam (ferric dimethyldithiocarbamate) (Foster and Henry, 1956). Despite as many as 30 spray applications during the 90-day infection season, infection levels of 15% to 20% are not uncommon (Rowan, 1972). Most of these infections occur in April and early May during the first few days after seed germination. This is the most difficult time to adequately protect seedlings because the germinating seedlings are rapidly elongating, exposing new succulent tissue to infection; and spring rains often make the nursery impassable for spray equipment (Rowan, 1977).

Other fungicides, especially systemics, have been used experimentally to control fusiform rust with some success. Soil drenches of benodanil or benomyl have proven effective in greenhouse trials (Hare and Snow, 1976). Other chemicals have been tested as foliar sprays, but variable levels of protection have been provided when compared to ferbam (Rowan, 1972, 1977). Coating pine seed with selected fungicides has proven ineffective (Rowan, 1972). This would be expected unless the fungicide was either absorbed through the seed coat or washed off the seed and absorbed by the emerging radicle. Chemicals can penetrate the seed coat of pine (Biswas, et al., 1972), but fungicides have not been studied extensively. Permeation of agronomic seeds with fungicides has been effective in the control of certain fungal diseases (Maude and Kyle, 1970).

The objective of this paper is to discuss the results of two experiments with systemic fungicides used in controlling fusiform rust. One experiment tests the efficacy of benodanil (2-iodobenzanilide) as a foliar spray in nursery field trials. The other tests two systemic fungicides as seed treatments. The chemicals included: benodanil and bayleton (1-(4-chlorophenoxy)-3, 3-dimethyl-1-1(1H-1,2,4-triazol-1-yl)-2-butanone.

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The authors are indebted to G. P. Finger, L. A. Achimon, and W. J. Boeckman for their cooperation and assistance.

MATERIALS AND METHODS

Experiment 1. This experiment was carried out over two years (1976 and 1977) at the Weyerhaeuser Nursery in Aliceville, AL. The 1976 trial consisted of three treatments:

(a) Control - no preventative treatments
(b) Ferbam - applied at the rate of 275 g a.i./ha through the spring and early summer.
(c) Benodanil - four weekly applications at the rate of 370 g a.i./ha, beginning about 14 days after sowing when seedling emergence had just initiated.

The 1977 trial included the above treatments plus two additional treatments:

(d) Benodanil - four weekly applications at the rate of 185 g a.i./ha
(e) Benodanil - four weekly applications at the rate of 740 g a.i./ha

The experimental design for both studies was a randomized complete block with three replications. At the end of the growing season, 1.5 LBM of seedlings were hand lifted from each treatment plot. The seedlings were counted, graded, sampled for morphological measurements and carefully examined for rust infections.

Experiment 2. The results of this study are reported elsewhere (Mexal and Snow, 1978). Seeds from the Mississippi flatwoods seed zone that were known to be susceptible to fusiform rust were stratified for 30 days, soaked in aqueous solutions of the fungicides for 24 hr, and surface dried. The concentrations selected (bayleton at 800 mg a.i./L and benodanil at 80 mg a.i./L) did not significantly alter the rate nor completeness of germination compared to seeds not treated with a fungicide (Mexal and Snow, 1978).

Seedlings representing three stages of development (Fig. 1) were inoculated with rust spores 18 days after the seed treatment using the method described by Snow and Kais (1972). Each treatment X size combination consisted of 24 seedlings and was replicated three times, which constituted a randomized complete block design. Inoculum was prepared from a mixture of aeciospores collected near Laurel, Mississippi, and Bogalusa, Louisiana. Rust infections were determined 12 months after sowing.

In another study, designed to test the effect of bayleton on the germination of various seed lots, three seed orchard lots and two seed sources were stratified for 30 days, soaked in bayleton (800 mg a.i./L) and germinated on cellulose wadding in a growth chamber (21°C). Germination was monitored for 28 days at weekly intervals.

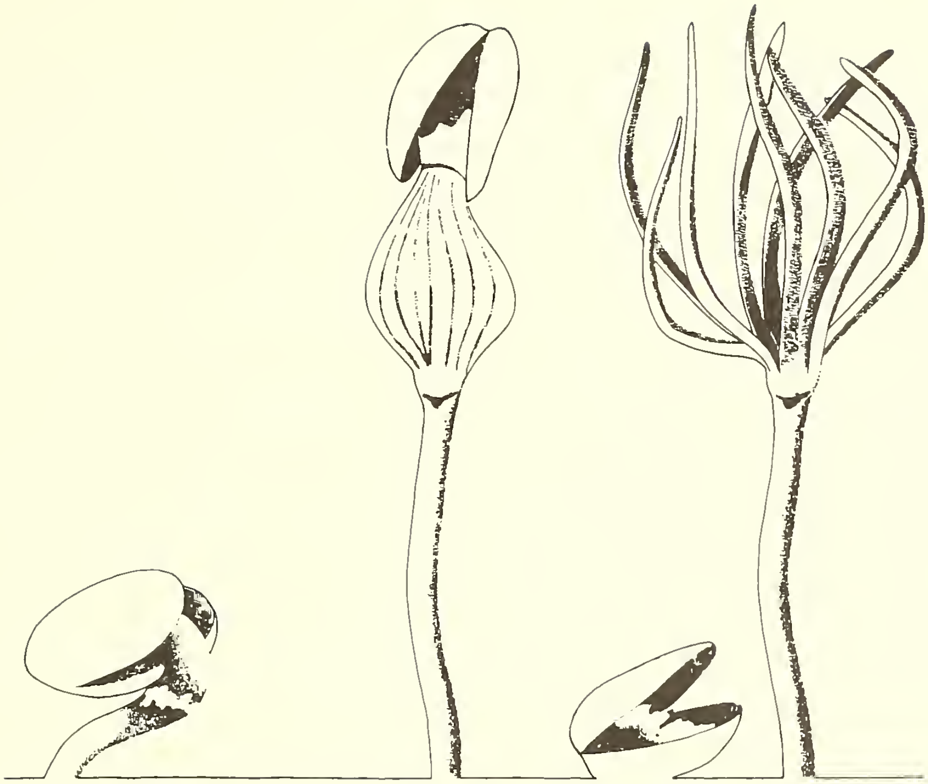

Figure 1.--Stages of seedling development at time of rust inoculation.

RESULTS

Experiment 1. Levels of rust infection were low both years the study was installed in the Aliceville nursery. In 1976, benodanil appeared to be as effective in controlling rust as ferbam. However, high variability among plots resulted in the treatment differences being insignificant (Table 1). In addition to decreasing rust infection, the systemic fungicide, benodanil, also decreased the level of mycorrhizal infection on the roots. The long term effects of this phenomenon are not known.

Table 1. Control of Fusiform Rust in 1976 Using Ferbam and Benodanil in Aliceville, AL Nursery.

Seed Source: Family 8-532

Treatment	Plantable Seedlings (%)	Height (mm)	Caliper (mm)	Mycorrhiza (%)	Rust Infection (%)
Control	50	161	4	77	2.8
Ferbam (40)*	58	158	4	93	1.5
Benodanil (4)*	46	140	4	33	1.6

*Number in parenthesis refers to number of applications during the growing season.

In 1977, all preventative treatments significantly reduced the incidence of rust infections compared to the control (Table 2). The differences among spray treatments were not significant, indicating four sprays of benodanil were as effective as over 30 sprays of ferbam. In this trial, increasing the application rate of benodanil did not significantly reduce rust infections.

Table 2. Control of Fusiform Rust in 1977 Using Ferbam and Benodanil in the Aliceville, AL Nursery.

Seed Source: Flatwood, MS

Treatment	Plantable Seedlings (%)	Height (mm)	Caliper (mm)	Rust Infection (%)
Control	67 *	180	4.5	2.7
Ferbam	67	178	4.8	0.7
Benodanil (86 g/a)	62	186	4.8	0.3
Benodanil (170 g/a)	64	202	5.1	0.4
Benodanil (340 g/a)	73	186	4.7	0.1

*Values opposite the same vertical bar are not significantly different (α = .01) according to Duncan's Multiple Range Test.

Experiment 2. Benodanil as a seed treatment was not effective in controlling rust; treated seedlings averaged 78% and the control seedlings averaged 82% (Table 4). However, since benodanil has been proven effective as a systemic fungicide on pine seedlings, this chemical probably did not permeate into the seeds in this test.

Table 3. The Effect of Seed Infusion with Systemic Fungicides on the Percentage of Seedlings Infected with Rust Galls 12 Months after Rust Spore Inoculation.

Chemical	Concentration	Seedlings with Galls or Lesions (%) Small	Medium	Large
	(mg/L)			
Benodanil	80	89 a*	71 a	71 a
NA_{43410}	300	88 a	76 a	90 a
Bayleton	800	14 b	22 b	22 b
Control	---	96 a	66 a	83 a

*Values followed by the same letter are not significantly different (α = .05) according to Duncan's Multiple Range Test.

Bayleton significantly reduced the incidence of rust infection. When the three size classes of seedlings were averaged, only 18% of those treated with this chemical had rust infections after 12 mos. (Table 3). The protection afforded by bayleton appeared to diminish as seedlings developed, but the increase in infection with increasing seedling size was not significant (α = .05). This would appear to result from a dilution or degradation of the fungicide as the seedling developed.

Bayleton at the rate of 800 mg a.i./L did not influence total germination of any of the seed lots tested (Table 4). In fact, the seed treatment significantly increased the speed of germination of three seed sources. However, it did not improve the germination of a lot (17-34) infected with Fusarium.

Table 4. The Effect of Bayleton (800 mg a.i./L) on the Germination of Loblolly Pine Seed.

Seed Source	Rust Susceptibility[1]	Germination	
		Control	Bayleton
	(%)		
17 - 27*	36	82 ± 9	83 ± 1
17 - 34	30	54 ± 5 (moldy)	37 ± 7 (moldy)
8-505*	29	93 ± 3	91 ± 3
Livingston Pa., LA	10	94 ± 4	92 ± 3
Howard Co., AR*	5	94 ± 4	92 ± 3

*Speed of germination significantly improved by treatment with Bayleton.

[1]Unpublished data (courtesy of F. E. Bridgwater).

FUTURE RESEARCH

These data, along with unpublished data collected by S. J. Rowan, G. A. Snow, W. D. Kelley, C. E. Cordell, and C. E. Affeltranger demonstrate the potential of controlling fusiform rust through the use of systemic fungicides. This year, Drs. S. J. Rowan, W. D. Kelley, G. A. Snow and I are testing both chemicals in nursery trials. Bayleton is being tested both as a seed treatment and as a foliar spray, and benodanil is being tested as a spray. Results to date indicate these chemicals can be as effective as ferbam and certainly more economical.

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FOREST NURSERY DISEASE MANAGEMENT
EASTERN SESSION - WILLIAMSBURG, VIRGINIA

S. J. Rowan[1/], E. L. Barnard[2/], and C. E. Affeltranger[3/]

INTRODUCTION

Thirty-three percent of all forest tree nurseries in the U. S. and 43 percent of the nursery acreage are located in the South. Southern nurseries produce 69.9% of the annual seedling crop. The average southern nursery is 63.9 acres in size, and 99.4% of its annual crop is bare root stock. Since at least three nurseries are under construction in the South, this region may be widening its lead in forest regeneration activity.

The high and increasing costs of producing nursery seedlings has increased the impact of disease losses. At the last Nurserymen's Conference in Charleston, I stated that the importance of nursery diseases is too often measured by the impact on seedling production. Too many responsible people, including many in attendance at this meeting, measure the importance of a disease by the number of seedlings lost in nursery beds. The real impact, however, is the loss in plantations due to the presence of a disease in nursery planting. Even a 1 percent growth reduction in a plantation over a 20-year rotation is a substantial monetary loss to a landowner.

OBJECTIVES

The objectives of our nursery disease management session are to inform you of recent developments in forest nursery disease research, to impress you with the importance of good disease control practices, and to stress the importance of seedling quality to survival and growth in plantations. This session is divided into two parts with a few minutes after each part for questions and answers. The first part will deal with fusiform rust and the last with black root rot.

CONTROL OF FUSIFORM RUST IN A SLASH PINE OUTPLANTING WITH A SYSTEMIC FUNGICIDE - C. E. AFFELTRANGER

One or two foliar and soil drench applications of the systemic fungicide benodanil during April and May successfully controlled fusiform

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The following adjuvants were tested at the indicated rates.

Triton X-100	1 pint/100 gallons
Triton X-45	1 pint/100 gallons
Plyac	1 pint/100 gallons
Exhalt-800	1 pint/100 gallons
Dupont Spreader Sticker	4 oz./100 gallons
Olde Worlde	1 pint/100 gallons
Ortho X-77	6 oz./100 gallons
Atlas Surfactant	4 pint/100 gallons
Security Spreader Sticker	1/2 pint/100 gallons
Plant-Gard	20 gallons/100 gallons
Bio-Film	6 oz./100 gallons
Nu-Film	1 pint/100 gallons
Ortho-Chevron Spreader Sticker	1/2 pint/100 gallons

It should be noted that the rating of the four adjuvants as superior in this test does not constitute an endorsement or recommendation for their use to the exclusion of others. Since all 13 adjuvants were equally effective without rain, a post-rain application that included any one of the tested adjuvants may have increased the degree of control obtained and probably would have made all 13 adjuvants equally effective.

MECHANICAL ROOT INJURY LOWERS SEEDLING SURVIVAL MORE THAN SEVERE BLACK ROOT ROT - S. J. ROWAN

Loblolly pine seedlings from six nurseries and slash pine seedlings from one nursery were planted on a deep sand (Lakeland) in Wilkinson County, Georgia. In nurseries where significant root rot was found, both seedlings with severe root rot and seedlings with little or no root rot were collected and outplanted. The amount of root rot on each group of seedlings was determined by measuring the length of primary and secondary roots and determining the percentage of their length with root lesions. Mechanical root injury was inflicted with a dull knife on loblolly seedlings of average quality from the Herty, Morgan, Continental Can, and Great Southern nurseries in Georgia. In this manner, numbers of feeder roots were reduced by 50% or 75%. The study design was a randomized block, with each of the five blocks containing 19 treatment rows of 25 seedlings planted at a 5-by-8-foot spacing. Seedling mortality was recorded 21 weeks after planting.

Although black root rot was severe on seedlings from the Hauss, Continental Can, and Great Southern nurseries, root rot increased mortality only in seedlings from the Hauss nursery (Table 1). Mechanical root injury, however, significantly increased mortality of seedlings from the Herty, Morgan, Great Southern, and Continental Can nurseries Root injury or seedling quality as measured by the number of feeder roots is a most important attribute of pine seedlings, and is significantly correlated with field survival. Root rot severity was also correlated with survival, but this correlation was barely significant at the 5% level (Table 2). Because mechanical lifting often destroys feeder roots, this nursery practice must be given very careful attention at all nurseries and steps must be taken to eliminate problems.

rust in a one-year-old slash pine plantation. Approximately one-half as many branch galls and one-quarter as many stem galls appeared on treated trees as those left untreated. The evaluation is continuing.

TIME BETWEEN APPLICATION OF FERBAM AND IRRIGATION IMPORTANT FOR FUSIFORM RUST CONTROL - S. J. ROWAN

Slash pine seedlings were sprayed with ferbam (4 oz. Dupont spreader sticker and 3 lbs. ferbam per 100 gallons) at a rate of 200 gallons per acre. Five, 30, 60, and 120 minutes after the ferbam sprays were applied, 1/4 inch of rain was artifically applied and the seedlings were inoculated with fusiform rust. The following percentages of seedlings were infected 6 months after inoculation:

Treatment	Percent infected
Nonsprayed-Check	94.7
5 minutes	43.0
30 minutes	27.1
60 minutes	13.5
120 minutes	7.2

The obvious conclusion to be drawn from these data is that ferbam sprays must be allowed to dry before irrigating or before rainfall begins.

SPRAY ADJUVANTS (SPREADER-STICKERS, SURFACTANTS) AND FUSIFORM RUST CONTROL - S. J. ROWAN

Although ferbam sprays have been used to control fusiform rust for several years in forest nurseries, very little attention has been given to the effects of spray adjuvants on the degree of rust control obtained. An adjuvant is any substance added to a formulation to improve the effectiveness of the pesticide. The term includes wetting agents, spreaders, emulsifiers, dispersing agents, foaming adjuvants, foam suppressants, penetrants, and correctives. A spray adjuvant may contain one or more surfactants, solvents, solubilizers, buffering agents, and stickers.

Because ferbam is a protective fungicide, its effectiveness for fusiform rust control depends upon the degree of coverage of susceptible pine tissue. Not only must the spray be applied to all susceptible pine tissue, it must also remain in place until the next spray is applied. Additional sprays are needed as seedlings grow and expose new tissues and after ferbam spray residues are removed by wind, rain, or irrigation. In essence, the effectiveness of ferbam sprays depends upon coverage, tenacity, and spray frequency. Coverage and tenacity are both affected by spray adjuvants.

All of 13 adjuvants tested were equally effective in the absence of rain, however, when 2 inches of rainfall were applied 2 days after spray application, four adjuvants proved superior to the other nine. These were Nu-film, Exhalt-800, Triton X-45, and Plant-Gard.

Table 1. Percent mortality of mechanically injured and black-root-rot-affected seedlings 21 weeks after planting on a deep sand in Georgia in January 1978.

Nursery	Pine species	Average seedlings	Root Rot seedlings	Seedlings feeder roots reduced 50%	75%
Herty, Georgia	Loblolly	1.6 a	0.0 a	5.6 ab	21.6 cde
Morgan, Georgia	Loblolly	15.2 abcd	-	23.2 def	37.6 f
Great Southern, Georgia	Loblolly	11.2 abcd	9.6 abcd	34.4 efg	57.6 h
Continental Can, Georgia	Loblolly	46.4 gh	19.2 bcde	76.8 i	83.2 i
Hauss, Alabama	Loblolly	24.0 def	47.2 gh	-	-
Walker, Georgia	Loblolly	12.8 abcd	-	-	-
Morgan, Georgia	Slash	7.2 abc	-	-	-

Means followed by a common letter do not differ at P=0.05 according to Duncan's Multiple Range Test.

Table 2. Relationship between black root rot severity and mortality 21-weeks after planting of pine seedlings on a deep sand in Georgia in January 1978.

Nursery	Pine species	Root Rot severity %	Mortality %	Seedlings lifted by
Morgan	Loblolly	0.2	15.2	Hand
Morgan	Slash	0.2	7.2	Hand
Walker	Loblolly	2.3	4.0	Hand
Great Southern	Loblolly	6.0	11.2	Mechanical
Continental Can	Loblolly	6.0	46.4	Mechanical
Herty	Loblolly	8.0	1.6	Hand
Herty	Loblolly	28.5	0.0	Hand
Hauss	Loblolly	38.4	24.0	Hand
Continental Can	Loblolly	39.0	19.2	Hand
Hauss	Loblolly	66.4	47.2	Hand
Great Southern	Loblolly	86.2	9.6	Hand

CHARCOAL ROOT ROT IN FLORIDA - E. L. Barnard

Charcoal root rot caused by Macrophomina phaseolina (Tassi) Goid. (= Sclerotium bataticola Taub.) is currently regarded as the most serious disease affecting pine seedlings in Florida tree nurseries. This disease was known to occur in Florida as early as the late 1950's and by the mid 1960's was considered to be the most important disease in at least three pine nurseries. In 1976-1977 the threat represented by charcoal root rot was dramatically emphasized in one Florida nursery where approximately 16.5 million pine seedlings valued at an estimated $148,000 were lost to the disease. First evidence of the problem was detected in late summer of 1976 and attempts to save the affected seedlings through a combination of root pruning, top pruning, and fungicide treatments were unsuccessful. In January of 1977 the seedlings were quarantined and plowed into the ground.

Charcoal root rot is particularly dangerous and warrants the attention of southern forest nurserymen for a number of reasons. For example, evidence of the occurrence of the disease in nursery seedbeds may be far less than dramatic. Above ground symptom expression may include nothing more than slight stunting and yellowing of affected seedlings. Indeed, even these symptoms may be masked as a result of the optimal growing conditions (fertility, irrigation, etc.) provided by the nursery environment. Consequently, the disease may be present and yet go unheeded as a problem of any significance. In addition, M. phaseolina increases in activity in late summer when soil temperatures are at their peak, often becoming problematic when remedial action may be too late to save the affected crop. Further, M. phaseolina forms persistent survival structures (sclerotia) in the soil which are resistant to many standard fungicides and soil fumigants, and which may remain viable in the soil for years. Finally, M. phaseolina not only attacks pines, it also attacks a variety of other plant species including cover crops such as corn and soybeans. As a result, this fungus can easily develop into economically disastrous populations if susceptible host crops are routinely grown in rotation in nursery soils.

While losses resulting from charcoal root rot may be incurred at the nursery in the forms of seedling mortality and/or increased numbers of cull seedlings, perhaps the most serious damages are sustained in terms of lost growth and replant costs resulting from plantation failures. Loss of and/or damage to seedling roots due to infection by M. phaseolina often results in seedlings which are unable to survive stresses (drought, etc.) in the field following outplanting. In Florida, outplant performance of diseased seedlings as well as the fate of M. phaseolina transported to the field on infected stock continue to be areas of concern and investigation.

Fortunately, effective control measures for charcoal root rot in the nursery are available. In addition to quality nursery practices, these include the use of non-host cover crops such as millet, rye, or a similar grain to avoid buildups in the fungus population and judicious application of a methyl bromide formulation equivalent to MC-33 at 350

lbs./acre under a 2 mil polyethylene tarp. Adoption of these measures in Florida is providing effective control of *M. phaseolina* in nursery seedbeds.

In summary, a healthy respect for charcoal root rot and the threat it poses to southern forest regeneration is encouraged. Particular caution is advised when considering management alternatives (cover crops; fumigation materials, rates, schedules, etc) which might serve to expand acceptably low populations of *M. phaseolina* into economically damaging levels.

NURSERY DISEASE WORKSHOP

Western Session - Hot Springs, Arkansas

Moderator - Charles E. Cordell[1]

Topic Discussion Leaders - T. H. Filer, Jr.[2]
A. G. Kais [3]
Walter D. Kelley[4]

ABSTRACT

The magnitude and variety of nursery tree seedling production and associated disease problems demands the utmost in disease protection and control applications in our southeastern nurseries. Significant disease problems on both conifer and hardwood seedlings include several root rots, stem diseases such as fusiform rust, and a variety of foliage diseases. An integrated control approach - incorporating appropriate cultural, biological, and chemical procedures - is considered as the most effective and practical method of minimizing nursery disease losses.

INTRODUCTION

There are presently over 55 state, industry, and federal forest tree nurseries in the Southeastern U.S. with an annual production exceeding 1 billion seedlings. New nurseries are being constructed annually - reflecting the present emphasis and future demands on reforestation in the south. This production represents over 75 percent of the annual tree seedling production in the U.S.. Southern nurseries produce some 15 species of conifers and over 12 species of hardwoods. The nursery sites represent a wide variety of nursery soils and environments from

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the mountains of western Virginia and North Carolina to the subtropics in southern Florida.

As might be expected, this wide variety of seedling species and nursery sites also has a corresponding wide variety of seedling disease problems. In addition, accelerating nursery operation costs and corresponding high-value products have significantly increased the impact of disease problems on both conifers and hardwoods. For example, nursery pest control costs such as soil fumigation presently average around $750-800 per acre. Seedling values have also increased sharply and presently range from $10.00 to over $200 per thousand seedlings.

Consequently, some of our highest forest resource values are represented in our nurseries, demanding the utmost in disease protection and intensive control procedures.

Our most important nursery disease problems and control procedures will be discussed in the following sections. As these selected topics are presented, full participation by all workshop attendees is encouraged.

CHARCOAL OR BLACK ROOT ROT OF SOUTHERN PINES

by

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Charcoal or black root rot, caused by the pathogenic soil fungi - Macrophomina phaseolina (Sclerotium bataticola) and several Fusarium spp., continues to cause severe widespread seedling damage in southern forest tree nurseries. During 1978, the disease was again observed in state and industry nurseries in Florida, Georgia, South Carolina, Alabama, Mississippi, and Louisiana along with the federal (Ashe) nursery in Mississippi. All species of southern pine seedlings are susceptible to this root rot disease along with some hardwoods such as sweetgum (Liquidambar styraciflua).

The most severe charcoal or black root rot damage observed to date occurred at the Andrews State Nursery in Chiefland, Florida during 1976. Approximately 16.5 million (over 50% of 30 million seedling crop) loblolly (Pinus taeda), slash (P. elliottii), longleaf (P. palustris), and south Florida slash (P. elliottii var. densa) seedlings were rendered unsaleable. This damage represented a monetary seedling value loss of approximately $150,000.

Charcoal or black root rot disease symptoms on southern hard pine seedlings involve blackening, resinosus or pitch soaking (charcoal appearance), and mortality of both secondary and primary root systems. Foliage symptoms may not be conspicuous - particularly during the early part of the growing season or where light to moderate root rot is present. Consequently, intensive root and soil examinations in both the field and laboratory are frequently required to evaluate this disease problem.

The nursery seedling losses caused by root rot, although highly significant to the nurseryman, may be relatively minor when compared with subsequent reforestation losses. Over 50 percent outplanted seedling mortality has been observed in several southern states during the past five years. Primary losses occur in field plantings of diseased seedlings resulting in submarginal tree survival and subsequent plantation failures. The major monetary losses involve those invested in site preparation, tree planting, and early plantation culture and maintenance. Field outplanting studies have also recently been established by several cooperating southern forest agencies to evaluate root rot losses on a variety of reforestation sites.

An integrated nursery disease control approach is also recommended as the most effective and practical method of minimizing root rot losses. These practices include utilization of non-host cover crops, seedling species - site manipulations, adoption of cultural practices such as soil tillage and fertilization to reduce disease spread and buildup, and effective preplant soil fumigation. The most effective fumigant for soil-borne fungi of this type is a methyl bromide formulation consisting of methyl bromide - 67% and chloropicrin - 33% accompanied with a minimum 2-mil thickness polyethylene plastic tarping.

HARDWOOD DISEASES IN PLANTATIONS AND NURSERIES[1/]

T. H. Filer, Jr.

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Root disease is the most important problem of hardwoods in nurseries with most mortality from damping-off occurring during the first 6 weeks of seedling emergence. The root rots can persist throughout the growing season and cause stunting that makes seedlings unsaleable. Chemical fumigation of nursery beds is the best control method available for root disease. Methyl Bromide, Vorlex, Dowfume MC-33, Telone C, or Chlor-o-pic will reduce production cost by controlling root diseases and weeds.

In 1978, *Cylindrocladium scoparium*, a fungus that kills seedlings or reduces their growth, was isolated for the first time from walnut roots at the Arkansas State Nursery at Little Rock. The fungus also infected yellow-poplar, cherrybark oak and sweetgum in the Winona, Mississippi, nursery. Soil fumigation was used to control the disease. Since walnut and yellow-poplar are particularly susceptible to the disease, bed rotation with loblolly or slash pines or with less susceptible hardwoods such as green ash or sycamore should be used to control it.

Leaf diseases occasionally cause problems in hardwood nurseries. In 1978 walnut anthracnose (*Gnomonia leptostyla*) caused defoliation and some mortality in the Oklahoma nursery at Washington, Oklahoma. The disease was controlled by spraying with Benomyl and Dodine.

During the past two growing seasons, anthracnose (Gloeosporium) caused severe defoliation and mortality of yellow-poplar at the Mississippi Forestry Commission nursery at Winona. The disease was controlled by applying Benomyl and Copper Oxide. Also, proper fertilization and water regimes help minimize the disease.

1/ This paper reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that all the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State or Federal agencies before they can be recommended.

Mention of trade names is solely to identify materials used and does not imply endorsement by the U. S. Department of Agriculture.

In hardwood plantations, canker diseases are of most concern to growers. In sycamore plantations, canker stain fungus (Ceratocystis fimbriata) is one of the most serious diseases. Losses are usually low, but in some areas a 30-percent stand loss has been observed. To keep trees free of the disease, care should be taken to avoid wounding stems. Where the disease is present, sanitation cuts of diseased sycamore trees should be made.

Canker diseases in cottonwood plantations contribute to the approximate 20-percent loss during the first and second years. Septoria canker (Septoria musiva) is the pioneer organism. Other fungi such as Fusarium solani (Fusarium canker), Cytospora chrysosperma (Cytospora canker), Phomopsis macrospora (Phomopsis canker), and Botryodiplodia sp. (Botryodiplodia canker) usually invade through wounds made by Septoria. Singly or collectively, these fungi cause mortality.

The fungi I have mentioned infect nursery stock and overwinter as mycelia or spores on cuttings stored for spring planting. When infected cuttings are planted, they may leaf out but approximately 20 percent are girdled before developing a root system. Mortality is increased by climatic factors that limit plant growth or cause plant stress. Survival can be increased by dipping cuttings in Benomyl (1 lb./100 gal. H_2O) before planting.

Leaf diseases are becoming increasingly important in cottonwood plantations. Three important leaf diseases are Melampsora rust, Septoria leaf spot and Marssonina leaf spots. In various geographic locations, each may be the prime cause of defoliation. In the lower Mississippi valley, Septoria leaf spot causes the most defoliation. In the upper Mississippi valley and in the Midwest, Marssonina and Melampsora rust cause most of the defoliation.

Septoria leaf spot caused 90 percent defoliation in several plantations during the summers of 1977 and 1978. Most damage appears to be associated with certain clones, so resistant clones are being developed at Stoneville. Several Stoneville clones released in 1970 resist the fungus. Additional clones should be released in 1979. At present, fungicides are available to control Septoria in cottonwood plantations. One or two chemical sprays annually may be necessary to break the disease cycle.

CONTROL OF BROWN-SPOT NEEDLE BLIGHT OF LONGLEAF PINE

A. G. Kais

Integrated control systems which include disease resistance, effective fungicides, and improved silvicultural practices are required to provide long-lasting control of Brown-spot needle blight of longleaf pine. The Diseases of Southern Pines Project and the Southern Institute of Forest Genetics Project at Gulfport, Mississippi are working together to develop the necessary technology for disease control.

Recent research accomplishments have been significant; (1) Outstanding resistance can be inherited in the F1 progeny of individual longleaf pine, (2) There is a gain of resistance by selection, (3) An efficient inoculation system has been developed for rapid screening of disease resistance in longleaf, (4) Pathogenic variability has been detected within the fungus, and (5) Bravo (Chlorothalonil), which has been registered for use against the disease, and Benlate, a systemic, are two fungicides showing effective control in greenhouse and field tests.

Current and future research plans are concerned with the developing of Genetical, Mycorrhizal-Cultural, and Chemical technology for controlling Brown-spot needle blight on longleaf pine. Hopefully, this program will produce; (1) an improved selection system for longleaf pine, (2) selections of brown-spot resistant populations and families of longleaf, (3) rapid, early height growth of seedlings, and (4) effective systemic fungicides for use against the disease.

Status of Fusiform Rust Control with Systemic Fungicides

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Since 1942, ferbam has been the standard fungicide used to control fusiform rust (*Cronartium fusiforme*) in forest nurseries. Ferbam is an effective contact fungicide; however, the number of applications (30-50/year) required to control fusiform rust in nurseries has made its continued use questionable for economic and environmental reasons.

In recent years systematic fungicides have been shown to be effective in controlling diseases of major agronomic crops. Generally, these chemicals are effective at lower rates and require fewer applications than are necessary with contact fungicides. Unfortunately, the costs of developing, registering and marketing a new fungicide are so high that chemical companies direct their efforts toward disease problems of major crops. This assures a market of sufficient magnitude to recover their investment plus a profit. New fungicides can be and often are labeled for use against pathogens of minor crops: however, such labels are secondary to the primary label for the major crop.

During the past few years several systemic fungicides have been tested for activity against *C. fusiforme*. Of these, benodanil (BASF-Wyandotte) and bayleton (Chemagro) are the most promising.

Benodanil has been tested more extensively than bayleton. The most promising rate and method of application was 20 kg active ingredients (ai)/ha (17.8 lb/ac) applied pre-plant soil incorporated. This treatment provided protection from fusiform rust for at least 40 days. Foliar sprays of benodanil applied at a rate of 0.99 kg/ha (0.88 lb/ac) provided protection for less than 13 days.

Unfortunately, benodanil is extremely active against ectotrophic mycorrhizae that are symbiotic with southern pines. In laboratory studies growth of these fungi was completely inhibited by benodanil at a concentration of 1.0 ug/ml in an agar medium. In the nursery, development of mycorrhizal roots was delayed through August following a soil drench treatment with benodanil at a rate of 30 kg/ha applied in April. Although seedlings had abundant mycorrhizae at lifting time, the delay caused by benodanil resulted in a high percentage of small, non-plantable seedlings.

BASF-Wyandotte has shelved further development of benodanil and it is improbable that this fungicide will ever be labeled and marketed.

Initial research results with bayleton indicate that this fungicide is more active than benodanil against *C. fusiforme*. Results of a test conducted at the U.S.D.A. Forest Service Rust Testing Center showed that bayleton applied pre-plant soil incorporated at a rate of 2.0 kg/ha (1.8 lb/ac) protected seedlings against fusiform rust for at least 40 days; thus, bayleton accomplished the same degree of protection as did benodanil but with a ten-fold reduction in the amount of fungicide required. Applied as a foliar spray at a rate of 0.56 kg/ha (0.5 lb/ac), bayleton protected seedlings against fusiforme rust for 21 days after application and also eradicated infections that occurred up to 7 days before the fungicide was applied. Thus, with a 28 day protection period the number of fungicide applications in a nursery conceivably could be reduced to a total of 2 during the spore release period.

Bayleton is less active against mycorrhizal fungi than is benodanil. In the laboratory, isolates of mycorrhizal fungi were not completely inhibited by bayleton until the concentration was greater than 5.0 ug/ml in an agar medium. Apparently, bayleton has no adverse phytotoxic effect on pine seedling. In the study at the rust testing center, no differences in seedling height was

observed between untreated control seedlings and seedlings growing in flats treated with bayleton at a rate of 5.0 kg/ha (4.46 lb/ac).

Bayleton is being evaluated in field plots in forest nurseries in the southeast this year (1978). Results from these tests should provide sufficient efficacy data to determine whether this fungicide should be labeled as a fungicidal control for fusiform rust.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

PRECAUTIONARY PESTICIDE USE STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key--out of the reach of children and animals--away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays of dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U.S. Department of Agriculture, consult your county agricultural agent or State Extension specialist to be sure the intended use is still registered.